Manfred von Ardenne - Translated by O.S. Puckle

AUTHOR

TELEVISION RECEPTION - Construction & Operation of A Cathode Ray Tube Receiver for the Reception of Ultra-Short Wave Television Broadcasting.

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TELEVISION RECEPTION

TELEVISION RECEPTION

CONSTRUCTION AND OPERATION OF A CATHODE RAY TUBE RECEIVER FOR THE RECEPTION OF ULTRA-SHORT WAVE TELEVISION BROADCASTING

BY

MANFRED von ARDENNE

TRANSLATED BY

O. S. PUCKLE

A.M.I.E.E.

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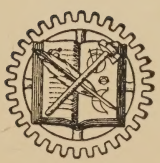

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FOREWORD TO THE ORIGINAL EDITION

THE technical worker is often reproached with the fact that he permits a high percentage of human effort to run to waste. To me, this reproach appears in the highest degree unjust, since, to give an up-to-date example, this same technical worker is also able to absorb the free time at his disposal by broadcast listening or by visits to the cinema, and since the correct balancing of one's personal activities is only a problem of organisation which each one of us must arrange for himself.

Perhaps in ten or twenty years' time, in the course of its development, television will occupy a place alongside broadcasting and the cinema as an equally important time-absorbing factor. At the time of the first practical experiments with cathode ray tubes, an adherent to this point of view would have been extremely optimistic. To-day, only a few years later, the problem is substantially solved.

The television outlook could only then be assessed approximately if one had had the opportunity of seeing television reception under the conditions which will later become normal. I have therefore employed the sound-film transmissions from the new Berlin transmitter to demonstrate television reception to some non-technical friends, none of us having seen these particular films before. The pictures were received on the research apparatus described in this book, and the result was satisfactory, in that the spectators watched the film with no less interest than that of an ordinary cinema.

The television outlook may in the future depend only partly on technical developments ; it is more likely to depend on the choice of programmes.

At the time of writing this book the turning point in the history of television development may have been reached. Thanks to the policy of fostering the advancement of television and to the foresight of the German Post Office, the first ultra-short wave television transmitter in the world (Berlin) has commenced

regular evening transmissions of pictures with a 180-line raster and 25 pictures per second. At the same time, the German State Broadcasting Company has undertaken the arrangement of the sound film programmes. Thus the moment came when television was taken out of the hands of physicists and technicians and was introduced to a steadily increasing circle of people and, finally, to the general public. Nevertheless, even at that time, the moment for the official introduction of a television service had not arrived. In principle the basic problem is solved and receivers can be manufactured, but two further problems await attention. The operation of receivers must be still further simplified and the cost must be reduced before the official commencement of a service, if there is to be no danger of a falling-off of public interest. Also, the Berlin transmitter has not, at the present time, sufficient stability for an official broadcast television service.

For the time being, and until the official introduction of a service, it would be to the interest of the further development of television if the largest possible number of engineers and amateurs would make themselves familiar with the problems of television. Not only will an increase in the number of people who are interested in the problems of television considerably increase the probability of further technical improvement, but it will also be possible for the authorities and for industry to become acquainted with the criticisms and the more important points of view of those receiving the programmes, before the commencement of an official service, on account of the large increase in the number of single observations. Last but not least, by fostering the construction of television apparatus by the advanced amateur and engineer, a number of technically proficient persons will become available who will later be of value in forming the nucleus of a television industry. The cost of building such television apparatus is quite considerable. In spite of this fact, the construction of such apparatus is entirely justified for the reasons mentioned above. The cost of the material for the receiver depends upon whether the equipment is to give first-class or average results or whether only simple experiments are to be carried out.

The purpose of this publication is to describe in its entirety the hitherto carefully guarded secrets of a few engineers, and to

provide an impulse towards intensive activity on the part of amateurs in the newest and perhaps most interesting branch of electrical engineering. The description of a complete commercially useful equipment will certainly not make this aim more difficult of achievement.

A further aim of this book is to give the scientifically interested reader an outline of the practical methods in use and the results obtainable. Finally, I hope that certain paragraphs will bring to the television specialist some fundamentally new ideas.

MANFRED VON ARDENNE.

LICHTERFELDE-OST.
December, 1934.

FOREWORD TO THE ENGLISH EDITION

NEARLY a year has passed since writing the German edition and, in the meantime, experience of the reception of television from the Berlin transmitter has shown that the present definition is not sufficiently good. It is therefore considered that at an early date the Berlin transmitter will be changed to another standard of definition with more lines and a greater number of pictures per second. Furthermore, two standards of definition have been decided upon in England and these will provide better picture definition than does the present Berlin standard. With reference to the new standards, which naturally demand a greater receiver band-width, one of the newly developed and more suitable picture receivers will be described in the English edition.

The Author is particularly pleased that the translation will be carried out by Mr. O. S. Puckle, who, together with Mr. L. H. Bedford, has brought to a successful conclusion a unique and very notable cathode ray tube method in the field of television.

LICHTERFELDE-OST.
August, 1935.

TRANSLATOR'S NOTE

THE Translator wishes to thank Baron von Ardenne and Mr. W. R. Bullimore, Managing Director of Messrs. A. C. Cossor, Ltd., for permission to translate the book. He is also indebted to Mrs. H. Nieter for assistance with the translation, to Mr. L. H. Bedford for reading the manuscript and to Marconi-E.M.I. Ltd., and Baird Television Ltd., for supplying information about the transmitted wave-forms used in the systems which are to be employed at the Alexandra Palace.

O. S. PUCKLE.

EDGWARE.
1936.

CONTENTS

		PAGE
	FOREWORD TO THE ORIGINAL EDITION . .	v
	FOREWORD TO THE ENGLISH EDITION . . .	ix
	TRANSLATOR'S NOTE	xi
CHAPTER		
I.	THE TECHNICAL PROBLEM	1
	A. Ultra-short Waves as the most Suitable Waves for Television Broadcasting	2
	B. The Television Transmitter, its Range and Transmission Data	3
	C. The Magnitude of the Field Strength at the Receiver	12
	D. The Requirements of the High-frequency Portion of the Television Receiver	13
	E. The Cathode Ray Tube as a Modulatable Light-source and Picture Analyser . . .	17
	F. The Most Important Requirements for the Time Base	19
	G. The Synchronisation of the Picture Scanning .	22
II.	THE TELEVISION TUBE AND ITS OPERATION . .	23
	A. The Reasons for the Superiority of the High-vacuum Type of Cathode Ray Tube for Television	24
	B. The Influence of the Space Charge on the Size of the Fluorescent Spot.	25

CHAPTER PAGE

C. The Connection between the Construction of the Tube and the Type of Ray Deflection . 26
D. The Ray Generating System in Television Tubes 29
E. The Brilliancy Characteristic and the Fluorescent Screen 32
Table I: Illumination Factors Measured at the Screen Surface 35
Table II: Abstract from: The Proceedings of the International Commission on Illumination: Geneva, 1924 . . . 39
Table III: Table of Approximate Wavelengths of Light in mμ. (millimicrons) . . 40
F. Various Types of Television Tube . . . 41

III. The Mains Supply Apparatus 47
(Power Unit)
A. The Circuit 47
B. Mechanical Construction Details . . . 51

IV. The Time Bases 54
A. The Production of Time Bases . . . 54
B. Self-running Controlled Time Bases or Distant Operated (not Self-running) Time Bases . . 57
C. The Time Base Discharge Valve and its Control 59
D. The Amplification of the Time Base Output Voltage 63
E. The Circuit of a Double Thyratron Time Base . 64
F. The Correct Adjustment of the Synchronising Impulse 68
G. The Production of the Balanced Deflection Voltages 69
H. Serious Faults and their Correction. . . . 73

CHAPTER PAGE

J. Construction and Operation of the Push-pull Time Base 75

V. The Amplitude Filter for Separation of the Synchronising Impulses 79

A. The Method of Operation of the Amplitude Filter 80

B. An Amplitude Filter using a Screen-grid Valve 82

C. Other Methods of Filtering Out the Synchronising Impulses 84

VI. The Detector 86

A. Rectification in the Cathode Ray Tube and its Disadvantages 86

B. A Full-wave Rectifier Circuit for the Second Detector and its Advantages 88

VII. The Ultra-short Wave Picture Superheterodyne Receiver 92

A. The Circuit of the Picture Receiver . . 93

B. Construction of a Superheterodyne Picture Receiver 99

C. The Installation of the Receiver . . . 101

D. The Aerial 105

VIII. The Sound Receiver 108

IX. Results Obtained 111

Bibliography 114

Index 117

TELEVISION RECEPTION

CHAPTER I

THE TECHNICAL PROBLEM

The problem of the faultless reception of a television transmission is only soluble if satisfactory solutions are found for a large number of separate problems. In particular, receiving and amplifying apparatus which will deliver sufficient alternating voltage to control the brilliancy of the picture and for synchronisation, together with sufficient power for the operation of the loud speaker in the sound receiver, will be required. The picture portion of the receiver must be free from inertia, since the light-dark transitions in the received picture must be reproduced with the smallest possible difference in definition from that of the transmitted picture. Furthermore, a modulatable source of light equally free from inertia must be used, so that the eye receives the impression of a small, sharply bounded and intensely luminous lightspot. The next problem is to obtain an auxiliary deflecting system to move the intensity-modulated lightspot over the surface on which the picture is to be formed. In order to modulate the picture correctly, one must take care that, at every instant, the lightspot at the receiver is in the same position in the picture frame, or format, as it is at the transmitter scanning-member; this is done by means of so-called synchronising impulses.

The quality of the received results is, within limits, dependent upon how far the above requirements are fulfilled. The above-mentioned limit is the definition at the transmitter itself. With a theoretically ideal receiver the quality of the received picture is limited by that of the transmitted picture. Since in a television receiver improved results nearly always imply improved transmissions, it is uneconomical to make the receiver able to produce better pictures than the transmitter can provide. All units described in this book are, in spite of this fact, designed so

as to provide a reserve over that required for the existing normal standards of definition, *i.e.*, 180 lines.

The above-mentioned problems will be further discussed in the following pages. Further explanations and examples of technical solutions of these problems will be found in the following chapters.

A. Ultra-short Waves as the most suitable Waves for Television Broadcasting

For high definition reception, which is alone capable of keeping popular interest alive, it is necessary that the receiver light intensity should be controlled by the transmitter from light to dark in almost a millionth of a second. As a matter of comparison it may be mentioned that almost ideal broadcast musical reproduction is obtainable if the receiver can follow transmitted variations in one ten-thousandth part of a second. The permissible inertia in picture transmission is some hundred times less than with broadcast sound transmissions. The inertia and the length of the necessary carrier wave are known to be connected with one another in a certain way. The shorter the wave the smaller is the inertia obtained from the whole transmission system. It has been known for some time that only waves of a few metres in length, the ultra-short waves, are suitable for television broadcasting. It is a fortunate condition that the ultra-short waves, up to a wavelength of some 10 metres, pass right through the upper layers of the atmosphere and do not, like the longer waves, return always to the earth's surface but radiate outwards in straight lines ; otherwise unavoidable interference would take place between the world's television transmitters later on. Were this not the case, only a few nearby transmitters could be put into service on the shorter waves on account of the greater band width of television transmitters. As a result of the straight line radiation these waves have two important properties : (*a*) field strength variations, such as frequently take place in the short wave broadcast band by mutual cancellation of waves arriving by different paths, and which are known as fading, do not exist ; (*b*) as a result of the almost direct radiation, the transmitter can only be received at a distance when its aerial is within optical range. This line-of-sight condition must not be too strictly accepted since the waves are bent by intervening objects and are able to penetrate non-conducting, or

PLATE I

FIG. 1.—The ring aerials for the Berlin vision and sound transmissions. (At the top of the Funkturm in the Exhibition Ground at Witzleben.)

[*To face p.* 3

poorly conducting, obstacles, such as walls of buildings, etc. With the still shorter waves, particularly those of less than 1 metre in wavelength, the condition of optical sight is always more strictly true. For this reason, in spite of the ease of modulation, they are not considered to be very suitable for television broadcasting. Furthermore, there is difficulty in producing transmitters of great power. Also the difficulties in the development of highly sensitive receivers which are easily workable are greater than in the case of the longer waves.

To keep the optical sight range as large as possible and to obtain the largest possible service area with an ultra-short wave transmitter it is necessary to arrange the transmitting aerials high above the earth.

B. The Television Transmitter, its Range and Transmission Data

This chapter and those following will show the basic technical details of the construction of, and the collected experience obtained with, the Berlin transmitter after more than one and a half year's experience in practical operation. In particular, the order of magnitude of the field-strengths at the place of reception (Lichterfelde-Ost, which is about 5 miles from the Berlin transmitting station in the Funkausstellung-Radio Exhibition-grounds) is given.

The aerials of the Berlin television transmitter are fixed on top of the Funkturm (radio tower). Fig. 1 shows both the aerials for the picture and sound transmitters. The aerials are fed from ultra-short wave transmitters which were built by the Telefunken Company and C. Lorentz Ltd., and which are designed for a large output. The construction of the Telefunken transmitter which transmits pictures from Berlin at the present time is shown in Fig. 2. This is a transmitter radiating about 16 kW. in the output stage, and a transmitter of the same type and output is used for the sound transmission.

Research has already been carried out on the possibilities of reception in Berlin and its neighbourhood.[1] This research has shown that the transmitter is satisfactory for Berlin and the nearby districts. The practical range of the transmitter is about 30 miles, which is 50 per cent. more than the optical sight

[1] W. Scholz, " Fernsehempfang in Gross Berlin " (" Television Reception in Berlin "), Funktechnische Monatshefte, Beilage Fernsehen und Tonfilm, No. 3, June, 1934.

range.[1] Tests with fine picture rasters are therefore only possible for people who are lucky enough to live very near to a television transmitter. Outside this range nothing can be done at present but to carry out special studies. Such tests are :—

(1) To experiment with long wave transmitters and very coarse rasters.

(2) To experiment with smaller transmitting units using cathode ray tubes for transmission ; these can easily be used, especially if the researches are limited to film transmission.[2]

(3) Study of picture rasters.

(4) Study of the high-frequency portions of television receivers by means of a small transmitter.

In order to clarify these matters, some practical conditions and results obtained in the service area of the Berlin transmitter will be given. The data for the Berlin transmitter, at the present time, are the following :—

Witzleben ultra-short wave transmitter :

Picture : 44,750 kc. (6·700 metres)
180 lines.
25 pictures per second.
Format 5 : 6.
Carrier amplitude (light) nearly 100 per cent.
Carrier amplitude (dark) 25 to 35 per cent.
Synchronising impulse by carrier interruption.
Line synchronising period about 5 to 7 per cent. of the line time.
Picture synchronising period about 5 per cent. of the picture time.

Sound : 42,950 kc. (6·985 metres).

The following data are given for the English transmitters :

Picture : 45,000 kc. (6·600 metres).

Sound : 41,500 kc. (7·228 metres).

The picture transmitter will have a maximum (white) carrier

[1] F. Baneitz, " Die Jüngste Entwicklung der Fernsehtechnik " (" The Latest Developments in Television Technique "), VDE Fachberichte, 1934, p. 121.

[2] M. von Ardenne, " Die Kathodenstrahlröhre und ihre Anwendung in der Schwachströmtechnik," p. 356, 1933 (English edition, " The Cathode Ray Tube and its Application in Small Current Technique," Sir Isaac Pitman Ltd., 1936).

Also L. H. Bedford and O. S. Puckle, " A Velocity Modulation Television System," *Journal I.E.E.*, Vol. 75, No. 451, July, 1934.

PLATE II

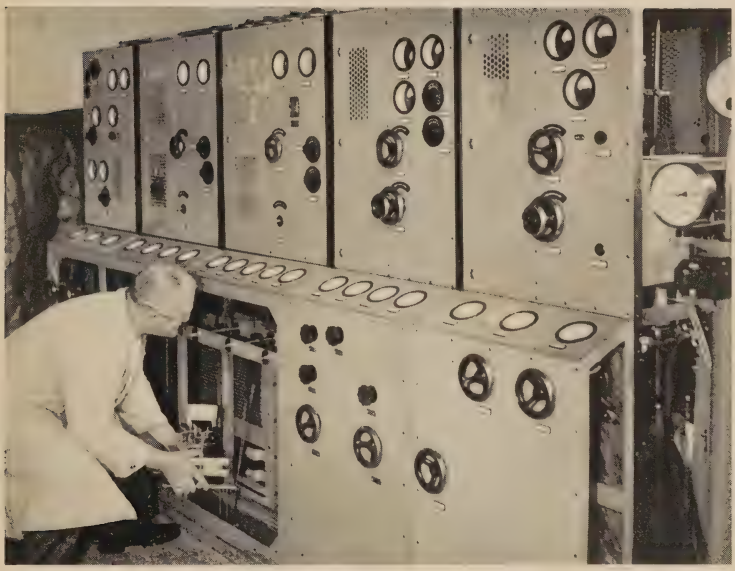

FIG. 2.—The Berlin (Witzleben) 16 kW. ultra-short wave television transmitter made by the Telefunken Company.

[*To face p.* 4.

power of 17 kW., while the sound transmitter power will be 3 kW. in the unmodulated condition.

Two companies are supplying television transmitting equipment, the Marconi-E.M.I. Company and the Baird Company. These transmitters, which will modulate separate radio transmitters, will be used during alternate weeks.

The equipment will be mounted in the Alexandra Palace, which is situated in a commanding position in North London.

Details of the wave-form emitted by the two television transmitters is given below.

MARCONI-E.M.I. TELEVISION SYSTEM

Specification of Radiated Wave-form

The Marconi-E.M.I. television system transmits 25 complete pictures per second each of 405 total lines. These lines are interlaced so that the frame and flicker frequency is 50 per second. The transmitter will radiate signals with sidebands extending to about 2 megacycles either side of the carrier frequency. Good pictures can be received utilising only a fraction of the radiated band, but naturally the quality of the received picture will depend upon the degree to which the receiver makes use of the transmitted band width. The transmitted wave-form is shown in Fig. 3.

(1) Line Frequency

10,125 lines per second, scanned from left to right when looking at the received picture.

(2) Frame Frequency

50 frames per second, scanned from top to bottom of the received picture.

(3) Type of Scanning

The scanning is interlaced. Two frames, each of 202·5 lines, are interlaced to give a total of 405 lines with a complete speed of 25 per second. The line component and the frame component of scanning are regularly recurrent, the interlace being derived from the fractional relationship between line and frame frequencies. An explanation of the method of interlacing is given at the end of this specification.

(4) Interval Between Lines

There will be intervals between the vision signals of successive lines, which intervals provide time for the transmission of a line synchronising signal and also provide time for the return of the cathode ray beam to the beginning of the next line. The minimum interval between the vision signal of successive lines will be 15 per cent. of the total line period (1/10,125 second), the first 10 per cent. of this interval between lines being occupied by the line synchronising signal and the remaining 5 per cent. by a

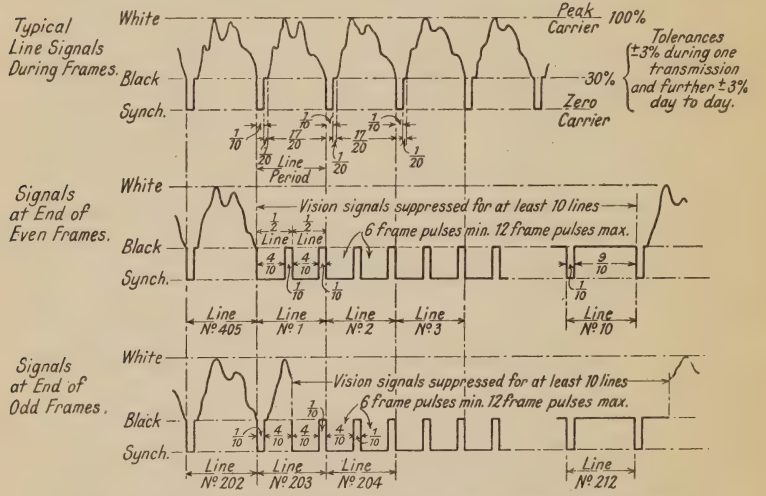

FIG. 3.—The Marconi-E.M.I. television signal wave-form.

signal corresponding to " black " in intensity. The remaining 85 per cent. of the total line period is available for transmitting vision signals.

(5) Interval Between Frames

There will be intervals between the vision signals of successive frames. The minimum interval between frames will be 10 lines, leaving a maximum of 192·5 active lines per frame, or 385 active lines per complete picture.

(6) Picture Ratio

The picture ratio will be 5 : 4, that is to say, the distance scanned during the active 85 per cent. of the total line period will

be 5/4 times the distance scanned during the 192·5 active lines of the frame.

(7) D.C. Modulation

The picture brightness component (or the D.C. modulation component) is transmitted as an amplitude modulation so that a definite carrier value is associated with a definite brightness. This has been called " D.C. working ", and results in there being no fixed value of average carrier, since the average carrier varies with picture brightness. The radio frequency transmitter output is specified in what follows as a percentage of the peak output. This percentage is in terms of current (or voltage) and not in terms of power.

(8) Vision Modulation

The vision modulation is applied in such a direction that an increase in carrier represents an increase in picture brightness. Vision signals occupy values between 30 and 100 per cent. of peak carrier. The amount by which the transmitted carrier exceeds 30 per cent. represents the brightness of the point being scanned.

(9) Synchronising Modulation

Signals below 30 per cent. of peak carrier represent synchronising signals. All synchronising signals are rectangular in shape and extend downwards from 30 per cent. peak carrier to effective zero carrier.

(10) Line Synchronising Signals

The line synchronising signals are of one-tenth of a line duration, and are followed by a minimum of one-twentieth of a line of black (30 per cent. peak) signal.

(11) Frame Synchronising Signals

The frame synchronising signals comprise a train of 2 pulses per line, each occupying four-tenths of a line and having one-tenth of a line interval of black (30 per cent. peak) signal between them. At the end of even frames, the first frame pulse starts coincident with what would have been a line signal. At the end of odd frames the first frame pulse starts half a line after the preceding line signal. At least 6 frame signals will be transmitted at the end of each frame, but the number may be increased to any number up

to 12 pulses (6 lines). During the remainder of the intervals between frames, normal line synchronising signals will be transmitted with black (30 per cent. peak) signals during the remaining nine-tenths of the line.

It will be noted that throughout the interval between frames (as during the whole transmission), the carrier falls from 30 per cent. to zero regularly at line frequency and in phase with the beginning of the normal line synchronising pulses.

(12) Variations in Transmitted Wave-form

The 15 per cent. interval between vision signals of successive lines and the 10 lines interval between successive frames are minimum intervals used at the transmitter. During the initial development of the transmitter, certain transmissions may have longer intervals between lines and between frames, which lengthened intervals correspond to the transmission of a black border round the picture.

The 30 per cent. carrier is the " black level " below which no vision signals exist and above which no synchronising signals extend. The mean black level of any transmission will be 30 per cent. $\pm$ 3 per cent. of peak carrier. The black level during any one transmission will not vary by more than 3 per cent. of peak carrier from the mean value of that transmission.

The residual carrier during the transmission of a synchronising pulse will be less than 5 per cent. of the peak carrier.

The line frequency and the frame frequency will be locked to the 50 cycle supply mains, and therefore will be subject to the frequency variations of the mains.

Explanation of Method of Interlacing

The method of interlacing is demonstrated in Fig. 4, which represents the top and bottom portions of the scanned area with the distance between the lines very much enlarged. The lines show the track of the scanning spot which moves under the influence of a regular downward motion (frame scan) with quick return and a regular left to right motion (line scan) with very quick return (not shown on drawing). The combination of these motions produces the slightly sloping scanning lines. Starting at A, not necessarily at the beginning of a line, the spot completes the line AB, returns to the left and traverses line CD,

then EF and so on down the " dotted " lines on the drawing. At the bottom of the frame the spot travels along line GH and then starts at J and travels to K. At this point the return stroke of the frame motion begins and returns the spot to L at the top of the frame. A complete frame scan has now been made since leaving A, so that 202–1/2 lines have been completed, and the point L is half a line away from A. The downward frame motion now starts again, causing the spot to travel along LM, completing a single line motion JKLM. The spot then returns to the left and traces out line NO, which, due to L being half a

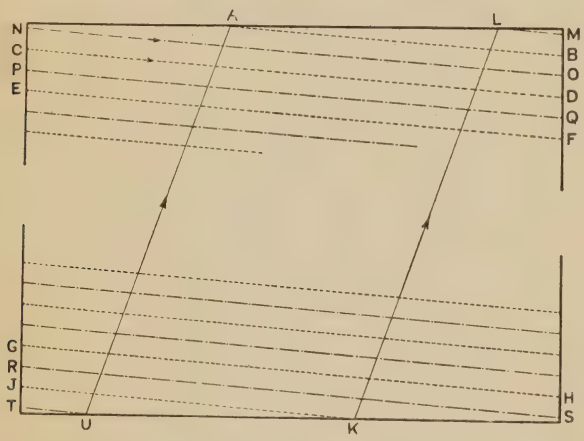

FIG. 4.—The Marconi-E.M.I. television system. Diagram of interlaced scanning.

line ahead of A, will lie between lines AB and CD. Similarly the next line PQ will lie half-way between CD and EF. The spot now traces down the " chain dotted " lines to RS and finally traces out TU, at which latter point the frame return causes the spot to rise again to the top. When the spot reaches the top it will have completed 2 frames since leaving A, and, as 2 frames occupy the time of exactly 405 complete lines, the spot will return exactly to A, after which the cycle begins again.

From the foregoing, it will be seen that the complete picture is scanned in 2 frames, but as each frame contains an integer number of lines, plus a half, the 2 frames will interlace. The system does not require the short return times shown for the line and frame scans, nor need the lines begin in the positions shown.

Provided the line and frame traversals are regularly recurrent and have the correct frequency ratio (2 frames = odd number of lines), an interlaced picture will be obtained.

DETAILS OF THE SIGNAL RADIATED BY THE BAIRD COMPANY'S APPARATUS

Wave-form

Fig. 5A gives complete details of the wave-form for picture modulation and synchronising impulses. From this it will be

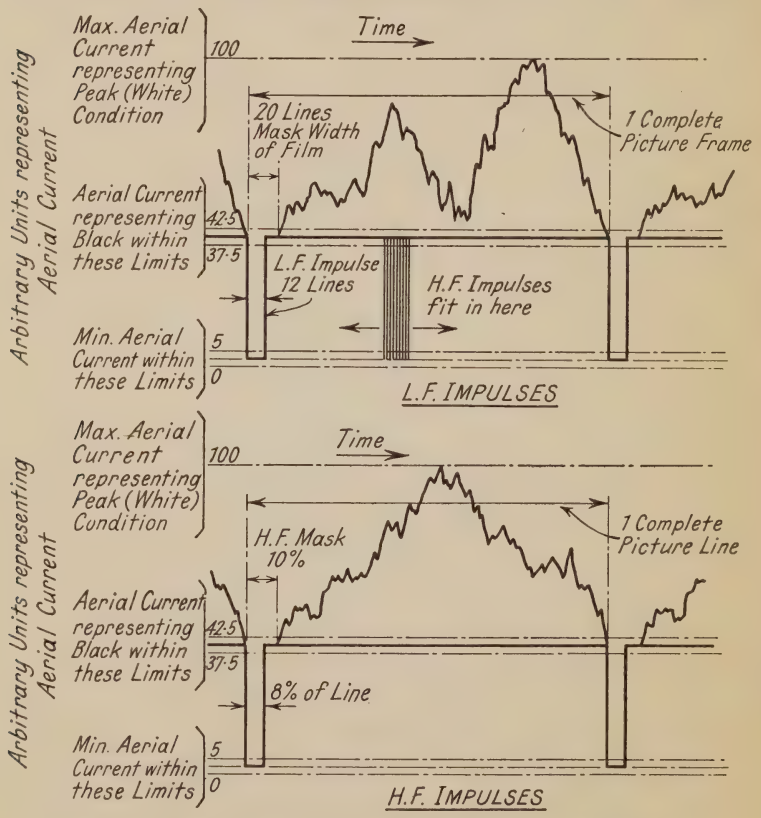

FIG. 5A.—The Baird Company's television signal wave-form.

seen that, using the arbitrary aerial current units of zero to 100, the total modulation for synchronising (black) extends between

PLATE III

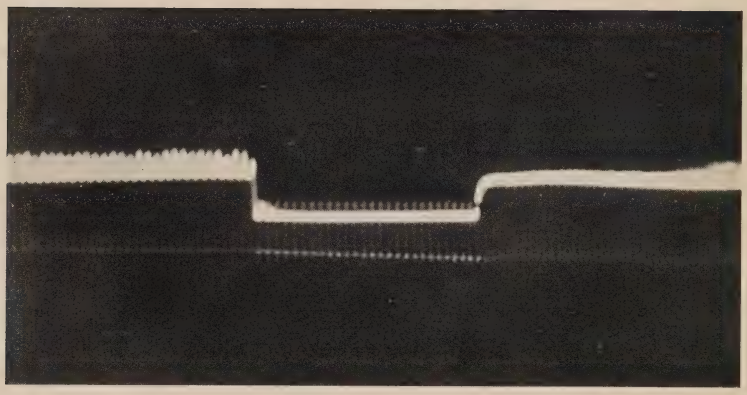

FIG. 5B.—Modified form of signal radiated by the Baird Company's vision transmitter in March, 1936.

[*To face p.* 11.

the tolerance limits of zero to 5 and 37·5 to 42·5, while the picture modulation (black to white) extends between the tolerance limits of 37·5 to 42·5 and 100.

It will be noted that the high-frequency synchronising impulse is rectangular in shape and is maintained for 8 per cent. of the total time taken in tracing the line, and occurs between the *line* traversals. The low-frequency synchronising impulse, which is also rectangular in shape, is maintained during the time that 12 lines are traced, and occurs between the *frame* traversals. These traversals, as seen by an observer looking at the received image from the front, scan from left to right (line) and from top to bottom (frame).

The diagram also shows that, in addition to the above 8 per cent. of the line traversal time occupied by the high-frequency synchronising impulse, a further 2 per cent. is masked off to form a black edging. Similarly, an additional 8 lines are masked off in the case of the low-frequency synchronising impulse for the same purpose.

Additional Details

The total number of lines in the complete picture is 240, scanned sequentially and horizontally at 25 picture traversals per second and 25 complete frames per second. The line frequency is thus 6,000 impulses per second and the frame frequency 25 impulses per second. The dimensions of the observed picture have the ratio of 4 horizontal to 3 vertical.

Amplitude modulation is employed, which results in light intensity modulation in the observed picture, the transmitter carrier increasing towards the white. The line synchronising signals and the frame synchronising signals are in the sense opposite to increasing picture modulation. The maximum frequency band involved in the transmission is 2 megacycles, and the average component of light in the picture is transmitted, a black in the picture being transmitted as black and a white transmitted as white, in accordance with the modulation percentages referred to above.

At the beginning of March (1936) it was noticed that the Baird Company were radiating a signal having a wave-form which differs from that shown in Fig. 5A. The new wave-form is shown in Fig. 5B, and since it contains a better form of picture

synchronising impulse it is to be hoped that the new signal will be adopted in the Baird transmitter to be installed at the Alexandra Palace. The signal is an improvement on that originally suggested because it ensures that the line time base continues to operate at the correct velocity and it therefore becomes unnecessary to pull it into step again at the commencement of each new picture scan.

C. The Magnitude of the Field Strength at the Receiver

The transmitter field strength at the receiver essentially influences the choice of the form of construction of the ultra-short wave receiver. From measurements made by the Reichspostzentralamt (German State Post Office), which are in good agreement with the results obtained in the author's laboratory, the field strength of the sound transmitter at 6 miles distance, in the roof-top, is only some 6 to 10 millivolts per metre. The field strength is thus only about a quarter of that of the original small broadcast transmitter at Witzleben at the same distance. The very poor results with the ultra-short waves may be accounted for by the absorption which takes place due to its distorted path through roofs, buildings and trees as it passes over the city. The use of the highest possible aerials, which are best arranged within the line of vision of the transmitting aerial, and the erection of loss-free feeders are advisable. A very important transmitter problem is that of increasing the field strength at the receiver so much that the dependence of field strength on transmitter distance is no worse than with a smaller transmitter in a broadcast service area. Since the field strength inside buildings is from 10 to 90 per cent. of that measured above the roof, depending upon the absorption ratio, it is practical to reckon that at a distance as small as 6 miles the field strength is not much greater than that of the stronger and more distant broadcasting stations in the evening. Except in the immediate neighbourhood of a television transmitter it is, at the present time, still necessary to use picture and sound receivers of almost equal sensitivity. It is, for example, necessary to use one of the sensitive intermediate-frequency receivers described in a later chapter at 9 miles distance from the transmitter, while sound reception with a back-coupled receiver is only successful if the reaction is made use of. For distances greater than some 12 miles from the transmitter, particularly for

the picture portion of the receiver, it is necessary to use a high-frequency stage. A method which is recommended for increasing the input voltage at greater distances from the transmitter is the use of a receiving aerial having a more or less directional effect. Especially in suburbs and in the open country, it is easy to erect directional aerials covering a large area and to arrange them to correspond with the direction of the incoming wave. Full details of the erection and balancing of such aerials have already been published. Aerials adjusted for the picture wavelength are suitable for picture and sound reception. One can certainly expect that, in the course of further development, the field strength in the transmitter service area will be substantially increased, if only in order to keep the cost of the high-frequency portion of the receiver as small as possible.

D. The Requirements of the High-frequency Portion of the Television Receiver

In order to reproduce sharply defined and undistorted pictures at a frequency of 25 pictures per second and with 180 lines, it is necessary that all frequencies from about 450,000 cycles per second, down to the lowest frequencies including the direct current component, shall be equally amplified in the receiver. With the data given above for the Marconi-E.M.I. transmitter the working frequency band extends up to almost 2 megacycles, while with the Baird transmitter the band extends only to some 750,000 cycles. In this book the theoretical interdependence of the picture quality and the electrical transmission data, particularly the carrier frequency band-width to be accommodated, will not be discussed, since articles treating them in a fundamental way have already been published in books and journals.

It may be sufficient to state here that the choice of circuit and of the values of the component parts of the picture receiver described later in this book are based on extensive consideration and calculation.

While, for the picture part of the receiver, circuits which differ considerably in various respects from the normal broadcasting circuits are required, in the sound part a normal audio circuit with back-coupling is, as a rule, satisfactory, if efficient low-frequency amplification is provided. Greater sensitivity and stability are obtainable if intermediate-frequency circuits are also

used for the sound receiver. Attempts to combine picture and sound intermediate-frequency receivers have met with success and, in this case, only a heterodyne oscillator and a mixing stage are required in addition. This is absolutely possible with the present normal frequency separation between the picture and sound wavelengths. However, the aforementioned compound circuit perforce brings with it limitations.

Since such limitations, in the existing conditions of development, can still adversely affect the operation, the sound part of the receiver described in this book is built as an independent unit.

An interesting and promising field of experiment which is certainly of considerable importance in the future development of television will be shortly described in the following lines.

It is obvious that an observer of the future television broadcasting, who must pay for his television apparatus, will only very unwillingly pay extra for a broadcast receiver. One will therefore have to consider later the construction of television apparatus which contains a broadcast, as well as a television receiver. On account of the greatly differing requirements a rational television-broadcasting combination may, at first sight, appear to be hardly realisable. In spite of this, closer consideration shows the existence of circuits which allow of such combinations. For instance, arrangements are possible by which the very efficient intermediate-frequency amplifier for the picture frequencies may have tuned circuits switched in, in front of and behind it, for broadcast high-frequency amplification followed by rectification and low-frequency amplification in the sound part of the television receiver. Besides numerous other combinations the following promising switching methods are possible :—

The vision intermediate-frequency amplifier may be joined to the broadcast receiver *viâ* input and output band-pass filters which have a pass-band of 10 kc. with a carrier frequency of, say, 200 kc. The rectifier and the low-frequency portion of the ultra-short wave sound receiver will be connected to the output band-pass filter, thus providing the normal methods of intermediate-frequency or second detection. In this case, the television intermediate-frequency amplifier will also be used as the broadcast intermediate amplifier. Hence, for broadcast reception, the mixing stage remains in an operating condition by being switched from the ultra-short wave circuit to the broadcast circuit. In

PLATE IV

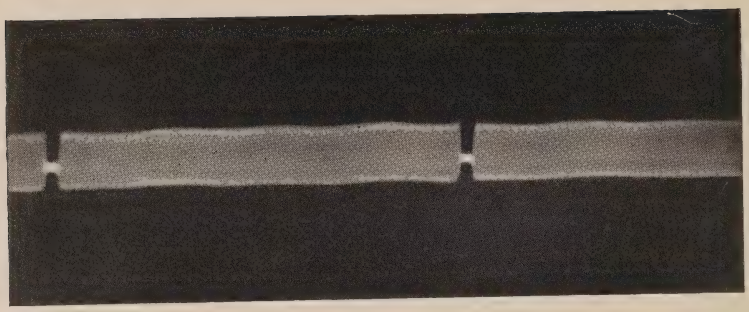

FIG. 7.—Oscillogram showing the high-frequency wave-form emitted by the Berlin (Witzleben) picture transmitter during a pause in the transmission (dark).

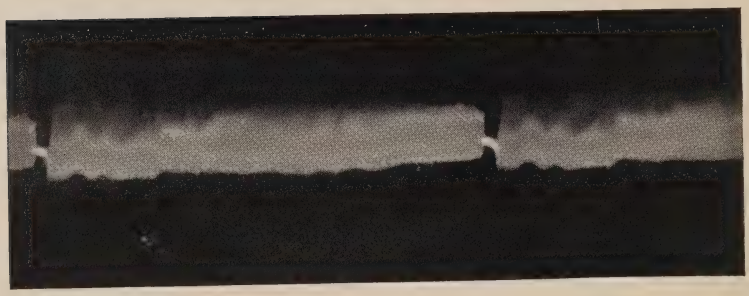

FIG. 8.—Oscillogram showing the high-frequency signal during a picture transmission.

[*To face p.* 15.

cases where no high-frequency stage is already provided for television reception, an auxiliary valve will possibly prove to be necessary in front of the mixing stage, solely in order that the necessary preselection may be secured for the broadcast range. It is very easy to obtain the required combination if a super-heterodyne circuit is provided for sound reception. In this case, it is necessary to arrange the input circuit and the tuned circuit of the frequency-changer so that they may be switched in and out. These suggestions may be sufficient to provide some ideas for further research.

On the left of the block schematic Fig. 6 a technical solution for the high-frequency portion of a complete television receiver which has, in general, proved satisfactory is shown, and this is further described below. The high-frequency voltage appears at the output of the aperiodic (independent of the frequency in the neighbourhood of the carrier wave) intermediate-frequency amplifier, and gives a true picture of the high-frequency wave-form sent out from the transmitter. Oscillograms of the received voltage at Lichterfelde-Ost from the Berlin transmitter are given in Figs. 7 and 8. Fig. 7 shows the oscillogram of the high-frequency wave-form during a pause in the programme when no picture is being transmitted. The radio transmitter is here adjusted to the value for darkness and is, in this case, at about 30 per cent. of its maximum amplitude, in agreement with the data given on p. 4. The interruption in the high-frequency wave-form which is observable in the oscillogram produces the synchronising signal which is sent out by the transmitter every $\frac{1}{25}$th of a second for synchronising the picture changes. A similar synchronising gap is inserted every $\frac{1}{4.500}$th of a second for line change synchronisation. The line synchronising signal is of such a short time duration that it cannot be seen in either diagram. The working point on the intensity control characteristic of the receiver light source is so adjusted that the value of darkness produced by the transmitter light source is accurately reproduced.

For transmitting the picture details, the Berlin transmitter uses, at the present time, a control range of between about 30 and 100 per cent. It is clear that in the oscillogram Fig. 8 the high-frequency wave-form depends upon the picture detail and upon the degree of modulation while the picture is being trans-

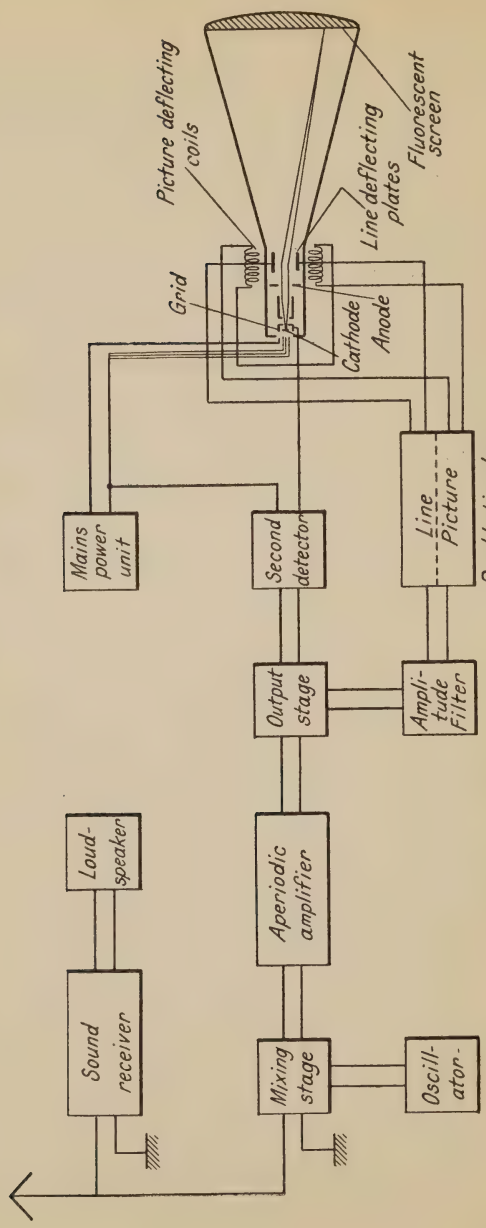

FIG. 6.—Schematic diagram of a television receiver employing a cathode ray tube.

mitted.[1] The synchronising period at the end of the picture can also be seen in this figure. The high-frequency voltage at the output of the receiver will, as shown in Fig. 6, be fed off in two directions. A so-called amplitude filter, the necessity for which will be fully described in a later chapter, serves to prepare the synchronising impulse. The second channel or path passes signals to the rectifier for controlling the intensity of the receiver light-source.

E. The Cathode Ray Tube as a Modulatable Light-source and Picture Analyser

The cathode ray tube has, in the course of the last few years, come into general use throughout the World as a modulatable light-source for television receivers; these tubes in their newest form give an extraordinarily bright and minute light spot, without expensive optical methods. The light intensity can be controlled in a practically inertialess manner and without critical influence on the spot size or position. The cathode ray tube as shown in the schematic Fig. 6 is, in its present form, a highly evacuated glass bulb of conical shape. At the end of the cylindrical neck is situated a cathode and, directly in front of this, the light (cathode ray beam) control electrode. The bias for the control electrode functions as does the bias for the control grid in a radio valve. After passing the control electrode, the electrons emitted from the cathode reach a positively charged electrode which plays a part similar to that of the screen-grid in a modern amplifying valve.

This electrode has only a very small hole through which the electrons pass. The electron cone, or beam, which passes through the hole will, with a correctly adjusted electrostatic field between the above-mentioned electrode and the final or main anode, again be concentrated to a small spot at the screen surface. The electric field between the correctly shaped electrodes operates on the electrons similarly to a lens system in optics, with light rays. In this connection one speaks of electron optics. Although the fluorescent screen, whose purpose it is to convert the kinetic energy of the rapidly moving electrons into light energy, is at a

[1] The asymmetry in the photograph Fig. 8 is brought about by too great loading, which is necessitated by having to tap off a high voltage for the oscillograph from the output of the intermediate-frequency amplifier.

great distance from the final electrode of the system, successful results are obtained by means of the electron-optical arrangements described in the next chapter, with very intensely luminous fluorescent spots of a diameter of less than 1 mm.

In contrast with amplifier valves, pressures of more than 1,000 volts are necessary and normal with cathode ray tubes. For the choice of such high voltages the following reasons are given in the order of their importance :—

(1) Good electron-optical images are only obtained with high acceleration.

(2) The influence of the space charge permits of high electron density only with rapidly moving electrons and, therefore, on those accelerated with high anode potentials.

(3) The characteristic of the fluorescent screen is greatly dependent upon the voltage. A good screen characteristic is obtained only with anode potentials of at least 1,000 volts.

As the strength of the currents in question are extremely small (less than 1 milliampere) one can easily arrange that the mains rectifier is not dangerous in spite of the high potentials. The remaining voltages for the operation of the cathode ray tube, viz., the filament heating, negative bias for the light control electrode (grid), and the lens electrode potentials are normally obtained from the same mains apparatus.

In spite of the high efficiency, which is a property of the cathode ray tube as a light-source, it would not so quickly have become popular if it could not have been used at the same time, and in a simple way, as an almost ideal picture analyser.

Picture analysis and reproduction by means of mechanical scanning devices (Nipkow discs, mirror wheels, etc.), which have been in general use for some years, have been, as prophesied by the author, almost entirely replaced by cathode ray tube analysis and reproduction.

How is picture analysis or scanning carried out ?

Only if 25 or, better still, 50 pictures per second are reproduced, does one obtain pictures sufficiently free from flicker, as obtained with the cinema. The technique employed must therefore be sufficiently skilful to enable a picture with extremely fine detail to be produced in $\frac{1}{25}$th or even $\frac{1}{50}$th of a second. With the above-mentioned type of picture analyser, which is normally in use to-day, the ray which produces the picture structure runs

in succession through 180 or 240 lines lying close to one another and without visible intervening spaces. For a picture size of, say, 14 × 18 cm. the ray has to move with a velocity of about a kilometre per second in order to cover the whole picture surface in the time available. At the same time, as mentioned above, the light intensity of the ray varies in about $\frac{1}{1.000.000}$th of a second, that is to say, it can be controlled, for instance, between light and dark in that time. These rigorous requirements cannot be fulfilled by apparatus involving simple mechanical principles and working with moving masses. The solution of this double problem lies in the use of the smallest possible particle, the electron.

The electrons moving in a ray or beam from the electron source to the screen of a cathode ray tube are relatively easily deflected by means of variable electric or magnetic fields in the desired direction and with the desired velocity. We have learnt in the last few years how to control the electrons in cathode ray tubes so that the latter obey the control with that remarkable precision which is necessary for the production of pictures of good quality.

F. The Most Important Requirements for the Time Base

As already mentioned above the ray source of the cathode ray tube provides an electron beam which is caused to impinge on the

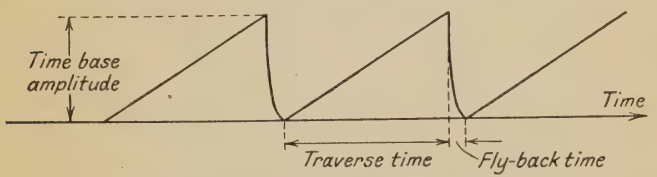

FIG. 9.—Graph of a time base oscillation.

fluorescent screen. Where the electrons strike there appears an extremely bright and sharp spot of about a square millimetre in size. By means of a change in the time-rate of emission the intensity of the light spot will be accurately controlled with a freedom from inertia comparable with that of the anode current in high-frequency stages of radio receivers ; that is to say, the inertia of the cathode ray tube is negligible. With the help of so-called time bases, the electric or magnetic fields are varied, and

these, in turn, deflect the electron ray in the vertical and horizontal directions so that it covers the surface of the fluorescent screen on which the picture is formed. In the block schematic Fig. 6 the two time bases, together with the deflecting plates and coils, are shown. The time bases produce voltages or currents having the wave-form shown in Fig. 9. The oscillogram of the time base current used for magnetic deflection is, for example, as shown in Fig. 10.

In order to obtain favourable picture reproduction the time base potentials must fulfil certain conditions : since the format used at the transmitter is to be accurately reproduced at the receiver the amplitudes for horizontal and vertical deflection, or, as they are frequently called, line and picture deflections, must bear a definite relation to one another. The absolute amplitude of the time base oscillation must be adjusted in accordance with the cathode ray tube data. As a rule the time base output is so adjusted that the corners of the picture just touch the edges of the fluorescent screen ; in this way the largest possible pictures are obtained. In order to avoid picture distortion, the time base wave-form must be as linear as possible. Furthermore, the time base circuit must be adjusted so that the flyback time is very small compared with the charging time. The flyback time must, in every case, be shorter than the synchronising time at the transmitter, because, otherwise, the flyback will cause interference or brightening in other parts of the picture. Finally, the time base potentials must have the required frequencies and must be in the correct phase, in order to show the picture being scanned at the transmitter, on the receiver screen without fault.

With a standard of transmission of 25 pictures per second and 240 lines, a time base frequency of 25 cycles per second for the vertical deflection, and one of 6,000 cycles per second for the horizontal deflection, are required. To illustrate the preceding sentence, Fig. 11 shows a television raster photographed with a smaller number of lines. One sees clearly the space between the individual lines. The sloping lines running through the raster are flyback lines which take place when the picture is completed. Each picture begins at the top of the screen and the lines are scanned from left to right.

In television reception the flyback lines which would seriously

PLATE V

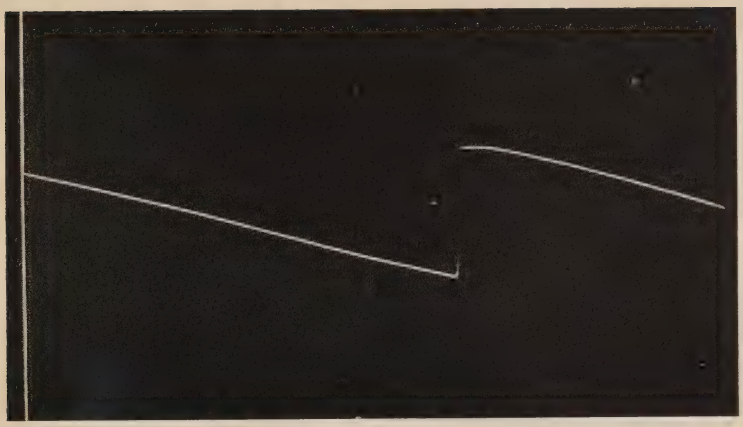

FIG. 10.—Oscillogram showing the time base current for magnetic deflection.

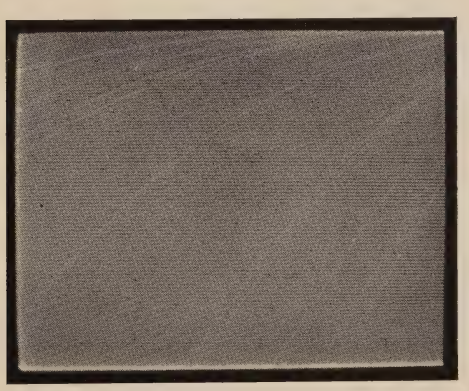

FIG. 11.—Television raster with a reduced number of lines (about 100). (Exposure time 0·15 sec.)

[*To face p.* 20.

PLATE VI

FIG. 12.—Oscillogram showing how a raster is scanned. (Picture frequency 25 cycles per second. Time frequency 2,500 cycles per second. Tube anode volts 4,000. Camera lens F. 2·8.)

[*To face p.* 21.

spoil the character of the picture are invisible, because the fluorescent spot is blackened at the instant of flyback by the synchronising signal from the transmitter.

Fig. 12 is a picture which very clearly illustrates the building-up of a picture raster with the help of two crossed time bases of different frequency. This almost continuous oscillogram was obtained from the picture shown in Fig. 11 by means of a camera which was swung round a vertical axis while the photograph was made. The photo shows the consecutive rows of single lines and permits one to see particularly well the change-over of the fluorescent spot from one picture to the next. At the same time this picture gives an impression of the high definition of the cathode ray tube. A variation of the above-mentioned analysing method is the use of slipping lines, *i.e.*, constant change of line position in the picture raster. The author has already referred (in a publication in the early part of 1931 [1]) to the value of line position change in connection with higher picture-change frequencies. At that time it was proposed that the line frequency should be so chosen that it was not a multiple of the picture frequency, in order to bring about a wandering of the lines. It has to-day become usual to choose the line to picture frequency ratio so that the whole picture surface is scanned once by a sequence of two pictures. (*Vide* Marconi-E.M.I. transmission data.) In one picture the even lines, and in the following picture the interlacing odd lines, are scanned. By the use of slipping lines the picture frequency may be doubled without producing any increase in the necessary frequency band. With the resulting 50 pictures per second, the flicker of the interlaced picture is almost entirely avoided. There remains some flicker between the lines, but this will only be found to be disturbing when the observer is too close to the picture. This effect is much reduced with large numbers of lines. In order to receive from a transmitter, working with the interlaced line method as described, it is only necessary to adjust the picture time base at the receiver to double the original frequency.

To illustrate the improvements which have been achieved in the definition of television pictures in the course of a year, the

[1] "Über neue Fernsehsender und Fernsehempfanger mit Kathodenstrahlröhren" ("On a New Television Transmitter and Receiver with Cathode Ray Tubes"), M. von Ardenne, Fernsehen, April, 1931, p. 70.

pictures Figs. 13, 14 and 15 (scenes from an experimental television film) are shown.

G. The Synchronisation of the Picture Scanning

One of the most important and difficult problems of picture reception is the question of synchronisation. For correct picture transmission, complete synchronisation between the scanning at the transmitter and the fluorescent spot position at the receiver is necessary, that is to say, distortionless pictures can only be reproduced if, at each instant, the scanning spots at the transmitter and receiver are in the same line and at the same distance from the beginning of the line. Variations of less than $\frac{1}{100.000}$th of a second are sufficient to distort seriously the picture definition. This obviously shows that the problem of synchronisation brings about unpleasant difficulties, particularly at great distances. The line and picture time base potentials are forced into the correct frequency and phase by the arrival of a short time impulse from the transmitter of such strength that it unlocks the receiver time base, *i.e.*, it starts the condenser discharge. These synchronising impulses for the line and picture time bases arrive always at the correct moment, *i.e.*, at the instant of line and picture change, from the transmitter and are brought about by short time-duration interruptions of the radiation, as suggested by O. Schriever.[1] In order that the strength of the synchronising impulse may at all times be independent of the contents of the picture, *i.e.*, the modulation, the insertion of an amplitude filter between the output of the receiver and the synchronising circuits of the two time bases is necessary. This amplitude filter is also shown in Fig. 6. With a well-installed transmitter and with a perfectly operating receiver, synchronisation is nowadays satisfactorily received, *i.e.*, the picture remains in position for a long time, and many hours of good reception are possible without further adjustment being necessary.

[1] O. Schriever, " Die technischen Einrichtung für einen Fernsehrundfunk nach dem heutigen Entwicklungsstand " (" The Present State of Development of the Technical Arrangements for Television Broadcasting "), Funktechnische Monatshefte, Beilage Fernsehen und Tonfilm, Vol. 6, June, 1933, p. 35.

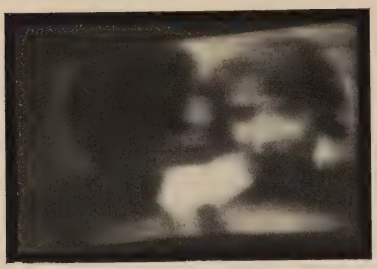

FIG. 13.—Fluorescent screen picture (December, 1930).

FIG. 14.—Fluorescent screen picture not re-touched (April, 1931).

FIG. 15.—Subjective quality of a 180 line moving picture (1936).

[*To face p. 22.*

CHAPTER II

THE TELEVISION TUBE AND ITS OPERATION

THE outstanding qualities of the cathode ray tube for television reception are summed up in the following lines.[1]

The fundamental advantages of the cathode ray tube are the following :—

(1) Elimination of all mechanical driving means, therefore absolutely noiseless operation.

(2) Only a small amount of power is necessary for deflection and modulation of the cathode ray tube so that the amplifier and synchronisation costs are relatively small.

(3) The position and brightness of the ray are not controlled by separate units as is the case with mechanical receivers.

(4) As a rule, there are no absorption or aperture losses since no optical lenses are employed.

(5) Ideal spatial distribution of light from the picture.

(6) The light from the beam can be used without any of it being screened off, *i.e.*, without any loss of screen light production.

(7) Because of the freedom from inertia of the ray one can use scanning methods in which sudden changes of the scanning speed are possible.

(8) The evenness of the picture raster does not depend on expensive, accurately made mechanical parts, but to a first approximation, only on the linearity of the deflection.

(9) It is possible to scan with varying numbers of lines per picture or pictures per second by simple changes in the circuit values.

(10) One can change over to other scanning systems by the use of simple switching arrangements.

(11) Cathode ray tubes can be manufactured with simple and cheap components.

[1] These sentences are taken from the chapter " Die Verwendung in Fernsehsender und Fernsehempfänger " (" The Use *of Cathode Ray Tubes* in Television Transmitters and Receivers "), which is a part of the book " Die Kathodenstrahlröhre " (" The Cathode Ray Tube "). See reference on p. 4.

A. The Reasons for the Superiority of the High-vacuum Type of Cathode Ray Tube for Television

Cathode ray tubes are divided into two groups. In one type the concentration of the moving electrons into a fine ray is carried out by filling the tube with inert gas at a definite pressure. Concentration occurs because the electrons, which are emitted with a small divergence angle from the cathode, ionise the gas. On account of the inertia of the gas ions, a positive space charge column is built up and draws electrons towards itself so that they surround it, whereupon they become concentrated into a fine ray.

In the second group the concentration of the electrons is brought about by one or more lenses and not by means of a gas filling. In this group the gas is removed as far as possible. One distinguishes therefore between gas-filled and high-vacuum cathode ray tubes. But there are still other intermediate types in existence in which, by an improvement in the electron optical conditions, a reduction of the pressure necessary for gas concentration has been achieved, thus combining the advantages of the gas-filled type with the advantages of the high-vacuum type. In spite of the fact that this intermediate type operates with lower anode potentials, that it has done useful work in the earlier television researches and that it still has a certain sphere of usefulness for measuring purposes, it will not be further described because, in future, only the high-vacuum type will be used for television. Where extreme brilliancy is required for special purposes, types of cathode ray tube with more or less critical compensation of the electron space charge by residual gas may, perhaps, be of importance. The known faults of gas-filled tubes (gradual failure of the spot sharpness and brightness, shortening of the life of the cathode by ionic bombardment of the oxide coating, marring of the raster by origin distortion or by oscillations which sometimes vary periodically and which are produced by charges on the glass wall of the tube, brightening of the dark parts of the picture by stray electrons, etc.) do not occur with high-vacuum tubes. The dependence of the light modulation on frequency due to the influence of ionic inertia, the limits in the range of control of the ray current and the variations in spot position caused by modulation of the ray are, in particular, avoided. In contrast with the gas-focussed type, the spot sharpness is maintained with high-

vacuum cathode ray tubes over the whole brilliancy control characteristic and also with the extremely high deflecting speeds which are required for large picture formats. The constancy of the tube characteristics are somewhat the same as are obtained with broadcast amplifying valves.

B. The Influence of the Space Charge on the Size of the Fluorescent Spot

As with amplifying valves, so also with high-vacuum cathode ray tubes, the mutual repulsion of electrons, *i.e.*, the negative space charge, is of great importance. The repulsion operates in such a way that, inside a cathode ray tube, the ray cross-section becomes enlarged where a large number of electrons are concentrated into a small cross-sectional area, for instance, in the neighbourhood of the fluorescent spot. The higher the ray current and the smaller the anode volts and the angle of convergence, the greater is the diffusion of the spot by space charge effects. The diagram Fig. 16 demonstrates this basic property of the high-vacuum types of cathode ray tube, which is independent of the arrangement of the ray producing system. On account of this space charge effect, it becomes clear that, for given tube constructions, the smaller the ray current and the larger the anode voltage the sharper will the fluorescent spot become. The dependence of the spot size upon the ray current begins to take effect with a certain value of anode current. As a rule it is recommended that the grid control voltage should not normally be allowed to rise above the value for maximum brilliance, at which point the increase of spot size begins. The tube dimensions are such that, with the spot diameter obtainable at this value of brightness, and with a given picture format, the whole screen is used with practically no gaps between the lines.

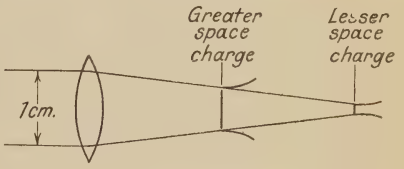

FIG. 16.—Diagram showing the space charge limitation of the smallest possible diameter to which a cathode ray beam can converge.

The usefulness of large electron beam convergence angles between the electron lens and the screen has already been mentioned above. Further, large convergence angles are of advantage

in the arrangement of the ray producing system, so that particular attention must be given to this point in cathode ray tube construction. As this question is of great importance in the development of deflecting arrangements it will be mentioned in that connection and the factors which lead to a limitation in the size of these angles will be discussed.

C. The Connection between the Construction of the Tube and the Type of Ray Deflection

The convergence angle determines the diameter of the electron beam at the place where deflection takes place and also determines

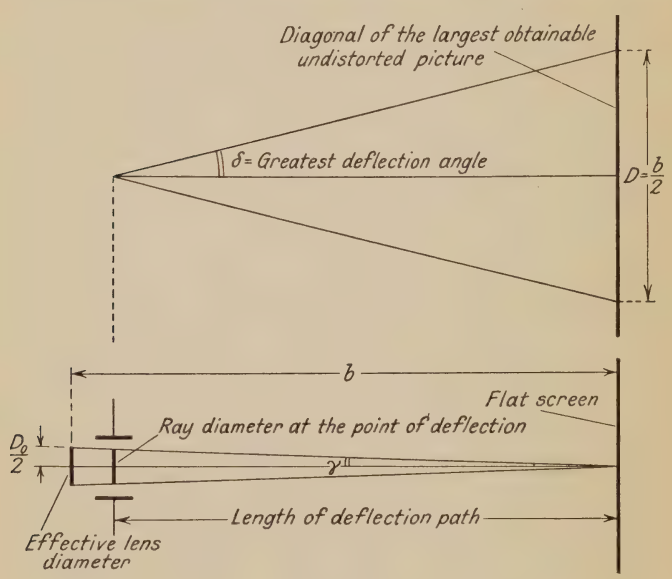

FIG. 17.

the lens diameter. These dimensions do not differ much, since the distance from the screen to the centre point of deflection is much the same as that from the screen to the lens, and they are generally considered to be of fixed size. Fig. 17 demonstrates this simple geometrical relationship. The distance from the screen to the centre point of deflection is obtained directly from the dimensions of the (sufficiently distortionless) picture to be viewed. Observation shows that the distortion occurring is, in

general, sufficiently small if this distance is made about one and a half to double the diagonal of the television image. Furthermore, it is not desirable to use longer distances because the distance between the screen and the lens must be made as small as possible in order to obtain a smaller spot (lower magnification). However, the requirement of greater deflectional sensitivity is not to-day of so much importance that one would use distances greater than that mentioned above because the method of obtaining the necessary strong deflecting fields at a moderate cost is now understood.

The value of increased convergence angles is referred to above. There remains, however, the question of the greatest permissible size of the convergence angle which must be determined. Since the distance between the screen and the electron lens is considered to be fixed, as mentioned above, it only remains necessary to make clear what ray diameter may be used at the deflecting point, without the fluorescent spot becoming critically enlarged or broadened into a line. If the spot, at the picture corners, attains a diameter greater than about one picture point, it is considered as critical enlargement. In the outer zones of the fluorescent screen a reduction of the spot sharpness is more likely to occur the greater the convergence angle. The greater the diameter of the electron beam at the deflecting point the smaller is the departure from the ideal homogeneous structure of the deflecting field which is sufficient to produce critical drawing out of the fluorescent spot into a line.

The most favourable conditions occur with magnetic deflection where it is easy to obtain very homogeneous fields with large ray diameters (for instance, with two large diameter coils mounted outside the tube). Magnetic deflection, if it is to be independent of the frequency, for frequencies above some 500 to 1,000 cycles per second, requires a very high power which is hardly practicable in a television receiver, unless ideal values are used for all the conditions affecting deflection. It appears, therefore, to be advantageous for the line deflection to be electrostatic and to use magnetic deflection only in the vertical (25 or 50 cycles per second) direction. With certain types of time base circuit, in which a traverse potential of small amplitude is amplified by means of an additional stage, one can obtain a deflection current almost as easily as a deflection potential, so that no essential

complication is introduced into the circuit by the use of magnetic deflection for one co-ordinate and electrostatic deflection for the other.

Even with the use of only one pair of plates for electrostatic deflection, the spot sharpness is reduced (defocussing occurs) with large deflection angles if the method of asymmetric feeding of the deflecting system, which has until now been in general use, is employed, as shown on the left of Fig. 18. With large ray diameters and unbalanced deflection the spot becomes oblong in shape at the edges of the fluorescent screen and cannot again be brought to a focus by further adjustment of the electron lens potentials. The deflecting plates affect the ray in the same way as a cylindrical lens. This very disturbing effect can, as research and consideration of the facts show, be avoided by using the symmetrical feeding arrangement shown on the right of Fig. 18.

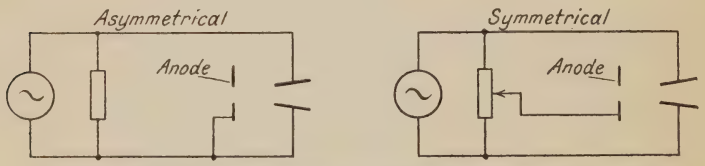

FIG. 18.—Two arrangements of the deflecting plates of a cathode ray tube for electrostatic deflection.

The symmetrical arrangement is absolutely necessary if electrostatic deflection is used in the vertical as well as in the horizontal direction. To make the matter completely clear it must be mentioned, that in cases where only one symmetrical voltage is available the latter must be connected to the pair of deflecting plates further from the anode. In spite of the fact that with symmetrical feeding of the plates and with electrostatic deflection in both directions, correct picture rasters covering the whole screen are obtainable, and that television tubes are not unduly complicated by the introduction of a second pair of deflecting plates, in the further discussions on the tubes developed by the author preference is always given to a method of mixed electrostatic and electromagnetic deflection. With the latter arrangement the known advantages of magnetic deflection remain, namely, convenient adjustability from outside the tube and the possibility of obtaining better spot sharpness with the same deflection distance in consequence of the elimination of the not incon-

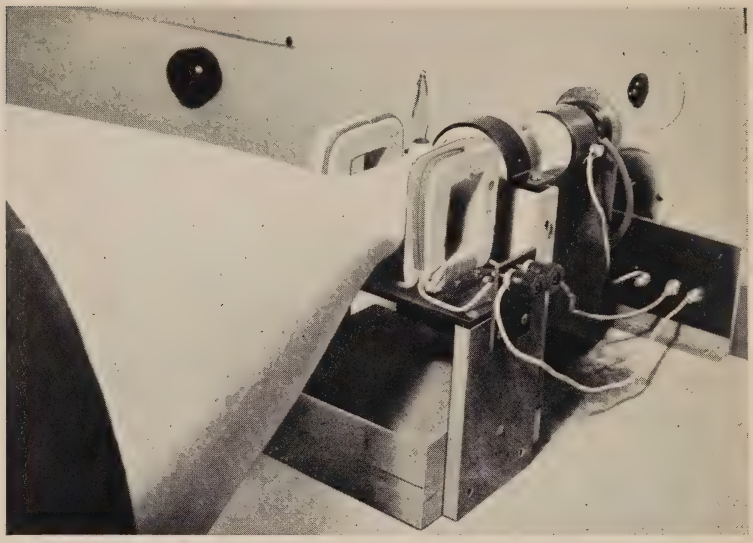

FIG. 19.—Arrangement of the deflecting coils for magnetic deflection in the vertical direction.

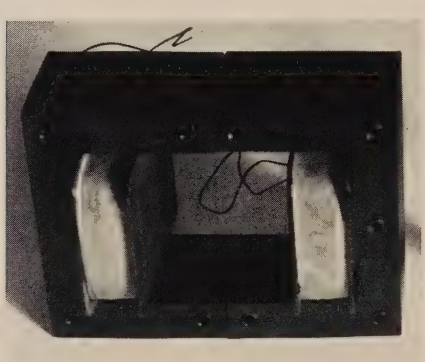

FIG. 20.—Deflecting coils having an iron core.

[*To face p.* 29.

siderable length of the second deflecting system. Furthermore, research proves that with mixed deflection the defocussing of the spot into a line at the edges of the screen, with the larger convergence angles, is not so noticeable as is the case when electrostatic deflection is used in both directions.

The deflecting arrangement must naturally be carefully considered so that the magnetic deflecting field does not interfere with the ray producing system. This condition will be satisfied with a neck width (5 cm.), as in the undermentioned tube, if the axis of the coils cuts those edges of the deflecting plates which face the screen. A suitable arrangement of the deflecting coils for magnetic deflection in the vertical direction is shown in the photograph (Fig. 19). By the use of a suitable size of iron core the necessary power for producing the picture deflection is reduced. However, the use of an iron core naturally involves a reduction in the fly-back velocity on account of the increased inductance. Research has shown, however, that iron core deflecting coils with a smaller number of turns are better than air core coils with more turns, but having the same inductance. With the iron core arrangement and with a given anode impedance of the time base amplifying stage, a simple variation in the air-gap between the halves of the iron core enables the fly-back time to be adjusted to such a value that the fly-back is just not visible in the picture.

Fig. 20 shows the arrangement of the iron core with the deflecting coils in position. Fundamentally, such a core may be relatively light in weight. There is no sense in making the reluctance of the outer magnetic paths extremely small compared with the relatively large reluctance of the unavoidable air space due to the large neck diameter, especially as increased weight and cost result therefrom. The spot sharpness with mixed deflection is consistently good right up to the edges of the screen, as shown in Figs. 11 and 12.

D. The Ray Generating System in Television Tubes

Several types of electron lenses exist which give good pictures even with the ray diameters obtained in practice.[1]

[1] A complete discussion on electron lenses will be found in the book " Geometrische Elektronenoptik " (" Geometrical Electron Lenses "), E. Bruche and O. Scherzer, Verlag Julius Springer, Berlin, 1934. See also

L. H. Bedford, M.A., " A Note on Davisson's Electron Lens Formulæ," *Proc. Physical Society*, Vol. 46, 1934, p. 882 ; and

V. K. Zworykin, E.E., Ph.D., " On Electron Optics," *Journal of the Franklin Institute*, May, 1933, p. 535.

For the construction of cathode ray tubes, either magnetic or electrostatic lenses are fundamentally possible. Magnetic lenses have the disadvantage that if one does not use permanent magnets a considerable amount of current is required. They are, furthermore, expensive to produce. For reasons connected with high-vacuum technique they are arranged outside the tube neck, thus large fields are unavoidable, that is to say, a lens of great thickness is produced. With electrostatic lenses more favourable conditions exist. Instead of having a current requirement they operate with a potential which is easily supplied from the normal mains rectifier. Furthermore, electrostatic lenses are very cheap to produce and are easily mounted inside the tube. Some types are extremely insensitive to stray effects from external electric fields. This particularly concerns lenses which are built up of electrode combinations with cylinders, since the cylinder walls function, at the same time, as screens. This is of great importance since, by this means, very compact forms of lens system construction are possible, supported on a single glass foot. In particular, the connections to the deflecting plates and to the other electrodes may pass in the immediate vicinity of the lens without distorting the configuration of the field. The aforementioned point of view serves to explain the fact that, in the construction of modern high-vacuum cathode ray tubes, only electrostatic lenses are employed. Among the different types of electron lens those forms which are known as accelerating lenses are found to be particularly suitable. With accelerating lenses (so-called, because they impart an acceleration to the electrons forming the beam) a relatively small magnification of the object is obtainable ; this results in a small, sharply defined, fluorescent spot, even when the distance from the object to the lens is small compared with that from the lens to the screen. The object, an image of which appears on the screen in the form of a fluorescent spot, is either the cross-section of the beam at some predetermined position, such as at the cathode surface or at the first diaphragm hole, or a virtual image of that cross-section. The use of accelerating lenses enables the overall length of cathode ray tubes to be reduced ; a factor which is of considerable importance when they are fitted into television receivers.

An approximate idea of the construction of the ray producing system of the television tube, with an electrostatic accelerating

lens, as developed by the author is given in the cross-sectional diagram (Fig. 21). There appears on the fluorescent screen an electron-optical copy of the cross-section S of the electron beam, which emanates from the cathode surface K, at the point where it passes through a hole in the centre of a thin diaphragm. The

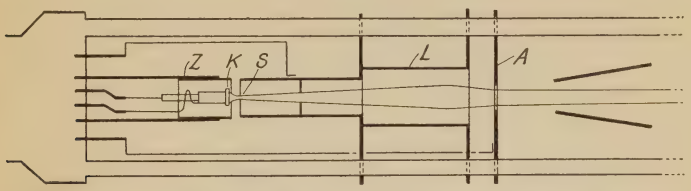

FIG. 21.—Schematic diagram of the author's high vacuum television tube.

image appears by the action of an electron-accelerating lens which consists of a cylinder L and a hole-electrode A. The adjustment of the focal length of the lens is effected by bringing the cylinder to a predetermined potential lying between those of the cathode and anode. This potential is, for a given system, always the same

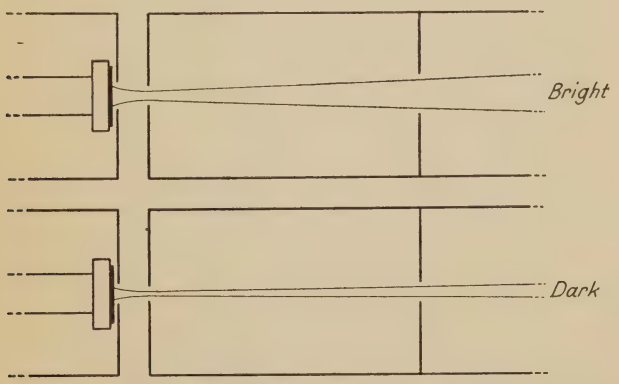

FIG. 22.—Effect of the brilliancy control on the form of the ray.

proportion of the anode voltage, and as long as the predetermined potential causes no current to pass to the cylinder, variations in the voltage of the anode current source will cause no change in the spot sharpness. This remark, of course, only applies so long as the cylinder and anode potentials are arranged to vary in the same proportion.

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The brilliancy control is operated by varying the negative bias potential on the light control electrode Z, which is situated in front of the cathode and which is pierced with a small hole. Since this electrode is in close proximity to the emitting surface, it has a relatively large control sensitivity. The influence of the bias on the ray path, in the system under consideration, is shown in Fig. 22. The more negative the bias, the smaller is the cross-section of the cathode which contributes to the emission, and the smaller is the divergence angle of the electron beam. In this system, particularly when in the bright condition, only the stray electrons have their path blocked by the diaphragms, *i.e.*, the system functions, not by stopping or by-passing already emitted electrons, but by controlling the quantity of electrons emitted by means of a control of the emitting area. The bias voltage should not be made so positive that any substantial part of the emission goes to the diaphragms, since, in this way, the cathode of the tube and also the anode current source will be unnecessarily loaded. Neither variations in electron velocity nor changes of spot position come about as a result of the control of ray intensity, so that television pictures are not spoilt by faults in the brilliancy control arrangements.

Fig. 23 shows the electrode system of a high-vacuum television tube which has been developed to a final state in accordance with the aforementioned theory. All the electrodes, including both deflecting plates, are supported on a glass foot.

E. The Brilliancy Characteristic and the Fluorescent Screen

The brilliancy characteristic of the cathode ray tube contains more information than does the anode current characteristic. The anode current and brilliancy characteristics for a modern high-vacuum cathode ray tube are shown in Fig. 24. These characteristics are taken only so far as the point where the diameter of the fluorescent spot becomes greater than the diameter of a picture element for a 300 line picture covering the entire fluorescent screen. The increase of light in the brilliancy characteristic due to the removal of the screen saturation effect, by distribution of the ray energy over the raster surface, is particularly interesting. The lower characteristic of those marked 1 in Fig. 24 (screen material No. 17) has been investigated, not only with reference to its efficiency, but also with regard to its saturation properties.

PLATE IX

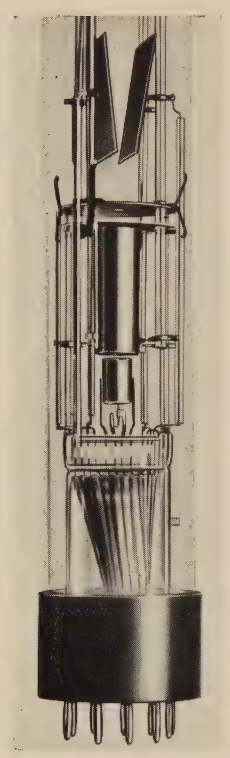

FIG. 23.—The electrode system of the author's high vacuum television cathode ray tube.

[*To face p.* 32.

Fig. 24 further shows that for the control of this system from light to dark, voltage variations of the order of 10 volts are sufficient.

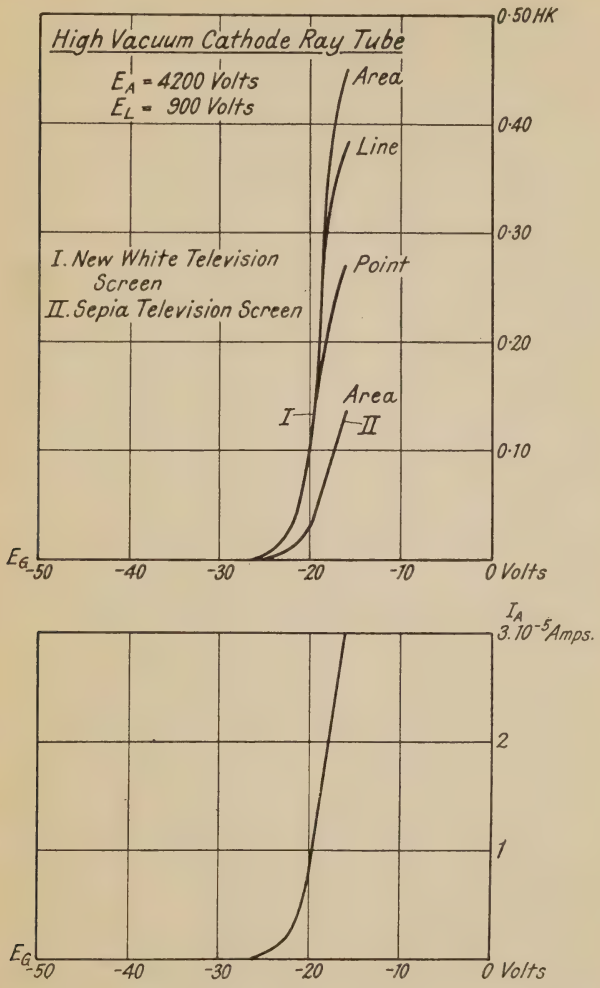

FIG. 24.—Anode current and brilliancy characteristics of the author's high-vacuum cathode ray tube.

The diagram Fig. 25 showing the characteristics for various anode volts is particularly informative. No doubt the brilliancy

characteristic of television tubes will, in the future, have the same significance as the anode current characteristics of amplifying valves.

In the construction of television equipment, the brilliancy characteristic permits of the predetermination of the illumination

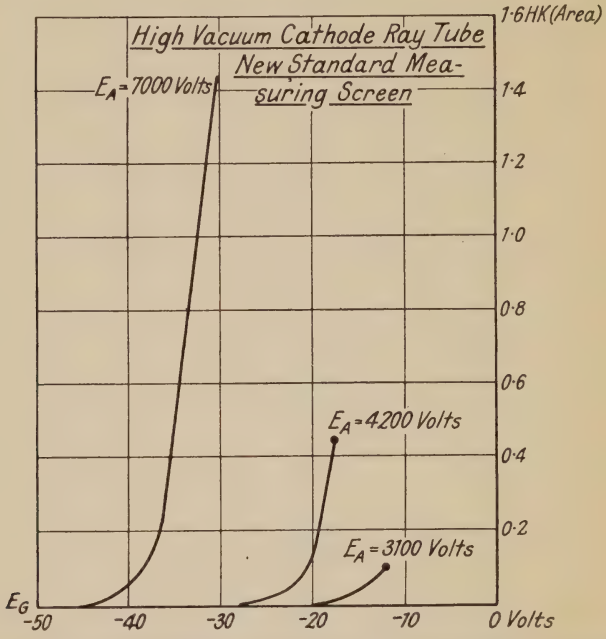

FIG. 25.—The brilliancy characteristic of the author's tube at various voltages.

of the raster surface for each value of the working bias and for any picture area.

From simple considerations there follows a known relation :—

$$\text{Number of lux for the picture surface} = \frac{10^4 \pi \text{ HK}}{0{\cdot}8 \text{ A}^2}$$

where HK = Hefner Candles, or
HK = C.P. × 1·1
A = picture area in sq. cm.

From the characteristic 1 (Fig. 24), and from the foregoing relationship, there results for a raster of 18 × 22 cm., a value of some 45 lux in the bright condition ; with a format of 13 × 16

cm., the corresponding value is about 80 lux. These raster brilliancies are of the order of brightness given by the average cinema. For television with 25 pictures per second they are already too great, since the author has made experiments which show that, with this picture frequency, the limit of flicker is reached with only 5 to 10 lux.

Only with a picture-change frequency of 50 per second is the tendency to flicker so far reduced that no further notice need be taken of the effect when the raster brilliancy is increased. The use of increased anode voltages, up to 4,000 volts, which, as the characteristic curves of Fig. 25 show, leads to a further very considerable increase in the slope of the brilliancy characteristic, is thus only of value with a high picture-change frequency.

TABLE I.—*Illumination Factors Measured at the Screen Surface.* (Measured with 4,000 volts on the final anode and 0·05 watts/cm.^{2})

Materal No.	Name.	Eff. in HK (1·1 × Candle Power) per Watt.
1	Old Television Screen (afterglow) . .	1·06
2	Leybold Special Measuring Screen, green-yellow (530 mμ), no afterglow.	3·50
3	Zinc-Cadmium Sulphide, yellow . .	1·60
4	Coss YS 34 Zinc Silicate, matt green .	0·86
5	Zinc Silicate, S 101, green . . .	0·86
6	Zinc Silicate Copper, green . . .	0·48
7	Manganese Silicate, red, strong afterglow, easily burned.	0·15
8	A. No. 32 Zinc Silicate, yellow . .	0·53
9	A. No. 36 Zinc Silicate, yellow . .	0·28
10	Zinc Sulphide, yellow	1·54
11	A. Ch. 40 H. Zinc Sulphide, green-yellow .	3·30
12	Calcium Tungstate, blue	0·23
13	Cadmium Tungstate, blue-yellow . .	0·70
14	A. Zinc Sulphide, blue-green, afterglow .	1·75
15	Special Screen, green-yellow (550 mμ), no afterglow, easily burned.	4·50
16	A. Zinc Sulphide, yellow, strong afterglow	2·15
17	Lorenz-Leybold Standard Television Screen, white, small afterglow.	3·50

It is necessary to choose screen materials so that a high efficiency is obtained and, at the same time, so as to give to the eye a pleasing spectral intensity distribution—in other words, the colour of the light from the screen must be a pleasing one.

To provide a proof of the order of the efficiency and of the

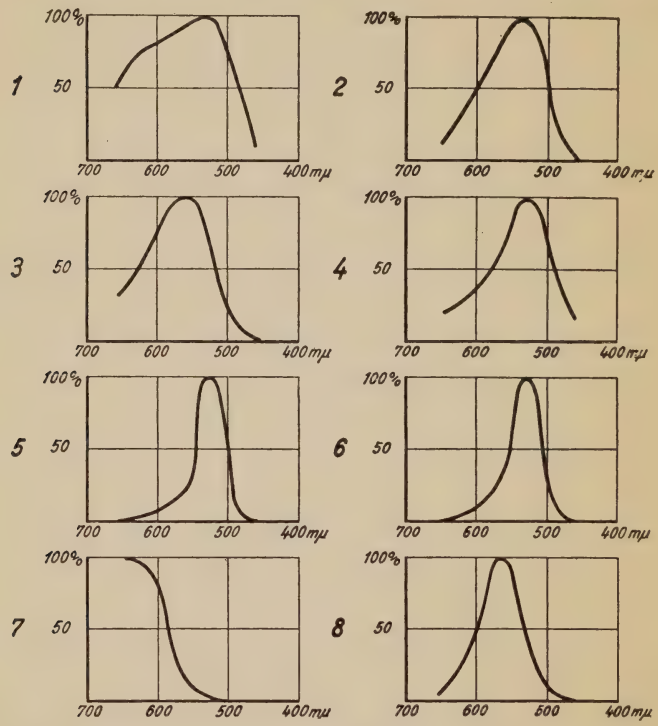

FIG. 26A.—Spectral intensity distribution of a number of fluorescent materials.

type of spectral intensity distribution, some measured results are given in the following lines.[1]

The measured efficiency of a number of materials which are used in practice, or which are of particular interest, are given

[1] M. v. Ardenne, " Über photometrische Untersuchungen und Messungen der spektralen Intensitätsverteilung an Fluoreszenzschirmen, insbesondere bei Erregung durch Electronenstrahlen " (" Photometric Experiments and Measurements of the Spectral Intensity Distribution in Fluorescent Screens Particularly with Electron Excitation "), *Zeitschrift für techn. Physik*, 1935, Vol. 16, No. 3, p. 61.

in the above table. The best results, with a relatively high beam current, are given with material No. 15, but since its spectral distribution is unpleasant to the eye, it is not used in the television tubes described herein.

In Figs. 26A and 26B are reproduced some very informative curves showing the spectral distribution of various screens in

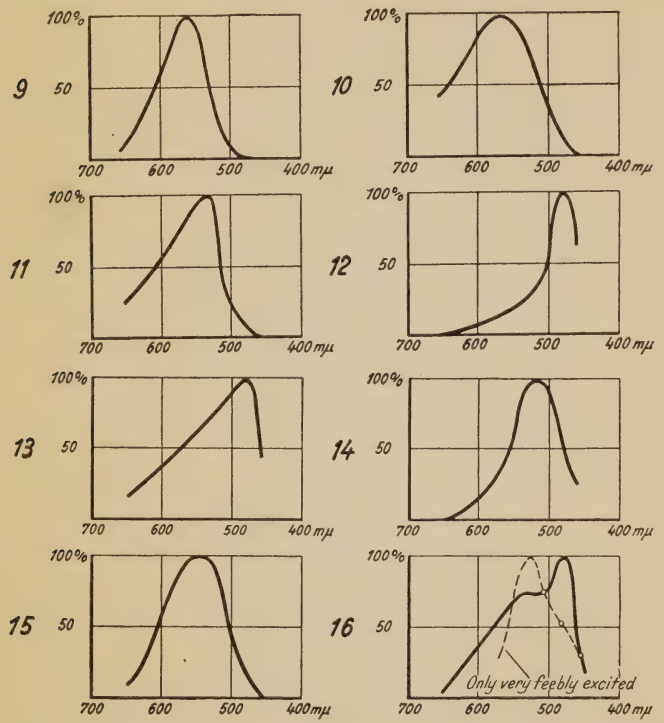

FIG. 26B.—Spectral intensity distribution of a number of fluorescent materials.

order to show their efficiency. So as to appreciate the relative visual brilliancy of these screens, reference should be made to Table II, which shows provisional values for the visibility factor of sources of illumination of varying wavelength. The measured results of the materials Nos. 1, 16 and 17 are extraordinarily interesting. These materials possess two spectral bands which are excited to a different degree with different values of anode

current. The measurements on material No. 16 show that, with high specific loading, *i.e.*, high beam current per square centimetre, the maximum illumination occurs at a wavelength of some 480 mμ (see Table III), while, with a lower load, the influence of the second band outweighs that of the first and the maximum illumination is given at a wavelength of about 540 mμ. Television pictures with these fluorescent materials have the peculiarity that the dark parts appear in a brownish hue, while the brighter parts are white. The explanation of the observed behaviour is given by the measurements shown in Fig. 27. The long wave band appears as phosphorescence and the short wave

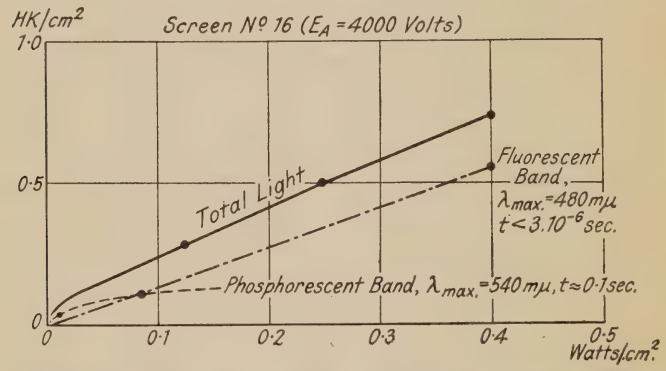

FIG. 27.—The dependence of the colour and efficiency on the specific loading of the screen with fluorescent materials of types Nos. 1, 16 and 17.

band as fluorescence. Since the phosphorescence, in contrast with the fluorescence, shows a pronounced saturation, the amount of illumination of the two bands, and, therefore, also the colour and the efficiency, must vary with the specific loading of the screen. For television reception the maximum loading is of the order of 10^{-3} to 10^{-4} watts per cm.^{2} if one disregards projection arrangements. The illumination ratio of the two bands is thus only important with very low screen excitation. As the measurements given in Fig. 27 show, a substantially more favourable efficiency is obtained below the bend in the curve than Table I would lead one to think, since the former gives results obtained with higher values of specific loading. The best efficiency and the most favourable spectral distribution will be found to occur with

material No. 17 of the table and with a loading of 10^{-3} watts per cm.^{2}, and as the measurements of Fig. 28 show, more than 90 per

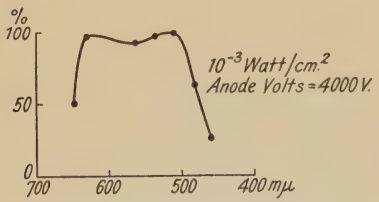

FIG. 28.—Curve of spectral distribution of the Lorenz-Leybold television fluorescent screen for black and white pictures.

cent. of the maximum ray intensity lies between 630 and 500 mμ and is white in colour.

TABLE II.—*Abstract from : The Proceedings of the International Commission on Illumination, Geneva,* 1924.

The following provisional values for the factor of visibility are recommended for general use. In special cases referring to extreme regions of the spectrum, or to particular conditions of extent of field, of intensity, etc., these provisional values may be incorrect.

Wavelength (mμ).	Relative visibility factor.	Wavelength (mμ).	Relative visibility factor.	Wavelength (mμ).	Relative visibility factor.
400	0·0004	530	0·862	650	0·107
410	0·0012	540	0·954	660	0·061
420	0·0040	550	0·995	670	0·032
430	0·0116	560	0·995	680	0·017
440	0·023	570	0·952	690	0·0082
450	0·038	580	0·870	700	0·0041
460	0·060	590	0·757	710	0·0021
470	0·091	600	0·631	720	0·00105
480	0·139	610	0·503	730	0·00052
490	0·208	620	0·381	740	0·00025
500	0·323	630	0·265	750	0·00012
510	0·503	640	0·175	760	0·00006
520	0·710				

In order to explain a further important peculiarity of the curve, apart from investigations with the spectral photometer, the spectra of the fluorescent light of the above-mentioned materials is given.

The spectra of materials Nos. 1 to 12 are given in Fig. 29. The number corresponding to that in the table and in Fig. 26 is again given at the side of Fig. 29.

TABLE III.—*Table of Approximate Wavelengths of Light in mμ (millimicrons).*

Colour.		Wavelength.
Ultra-violet		60–360
Violet	Visible Spectrum	360–455
Blue		455–492
Green		492–550
Yellow		550–588
Orange		588–647
Red		647–770
Infra-red		770–3,100

Note.—The violet is only visible from about 420 mμ upwards in wavelength.

The spectra in Fig. 29 show the extraordinary differences in the spectral distribution with different materials. While only the photographic efficiency is, as a rule, of value for their use as an oscillograph, for television reception the necessity for colours which are pleasing to the eye is of importance. It appears to be of fundamental importance in television to exclude those materials which have high efficiencies only over small spectral band widths. (See, for example, curves 5, 6 and 12, Fig. 26.)

The technique of photographic reproduction teaches us which colours are particularly pleasing to the eye. Next to the simple black and white tones, the brown-white (sepia) tones have found most popularity. Fig 30 shows the spectrum obtained by photographing lamplight on chamois paper. There are four different exposure times, the time being accurately doubled from each stage to the next. Analogous spectra for the material No. 1 in the table are given in Fig. 31. One can see that the intensity distributions of the two spectra show great similarities. In practice, pictures obtained with the brown tone of material No. 1 are extraordinarily pleasant. The latter remarks apply

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PLATE X

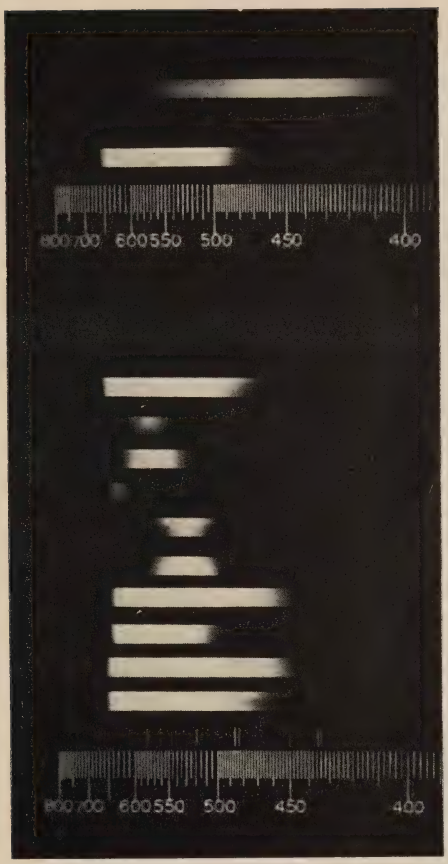

FIG. 29.—Spectra of various fluorescent screens.

[*To face p.* 40.

PLATE XI

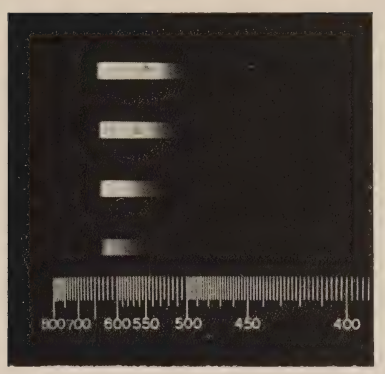

FIG. 30.—Spectrum of an incandescent lamp photographed on chamois (sepia) paper.

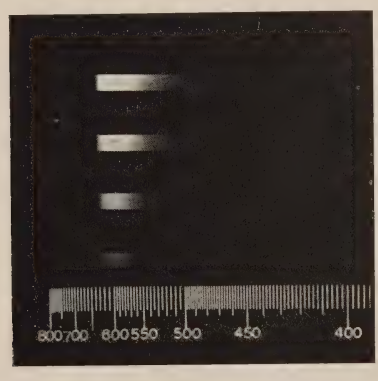

FIG. 31.—Spectrum of material No. 1.

[*To face p.* 40.

FIG. 32.—View of a non-metallised Leybold television tube with four deflector plates and a 30 centimetre diameter screen.

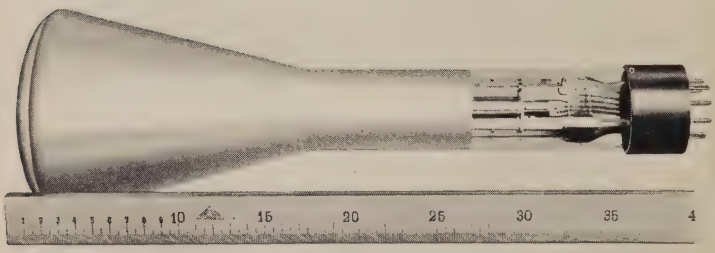

FIG. 33.—The author's small diameter television tube giving a black and white picture.

[*To face p.* 41.

also to the very bright, white coloured material No. 17, *i.e.*, the screen material used for the tubes described in this chapter.

F. Various Types of Television Tube

The ray-generating system, already described, with minor variations, is employed in bulbs of varying size. In the photograph (Fig. 19) part of a tube which will provide picture formats of some 18×22 cm. is shown. A view of the whole tube is shown in Fig. 32; in particular the relative sizes of the electrode system and the glass bulb are easily seen. The model in the photograph is intended for double electrostatic deflection, *i.e.*, in the horizontal and vertical directions. This type of bulb, which has a screen diameter of 30 cm., approximately represents the standard type for future home television receivers. Larger bulbs are difficult to make and require too much space, while, on the other hand, smaller bulbs give too small a picture, which is inconvenient, and which requires to be viewed from a distance which is uncomfortably close, especially for a large number of lines. For research, and for somewhat more modest purposes, there are smaller tubes, as shown in Fig. 33, which, together with the above-mentioned larger types, have been placed on the market by Leybold und von Ardenne Oszillographen-Gesellschaft m.b.H. of Cologne.[1] The picture sharpness, or definition, is the same with each size of tube. The normal tubes have only two deflecting plates, in accordance with the point of view already explained.

Depending upon the picture area which is to be illuminated and upon the required brilliancy and focus, the type of tube illustrated may be operated with potentials between 3,000 and 7,500 volts. For a raster of 300 to 400 lines the anode potential should not be less than 5,000 volts because of the small spot size which becomes necessary if good definition is to be obtained.

The voltage for the lower potential electrode of the accelerating lens, hereafter called the " lens potential," is adjusted to approximately one-quarter of the main anode potential. To control the brilliancy of the spot over the entire light-dark range, a bias variation of 10 to 15 volts is necessary, as shown in Figs. 24 and 25. The deflectional sensitivity with electrostatic deflection,

[1] English Agent, W. Edwards and Co., Allendale Works, Vaughan Road, Loughboro' Junction, London, S.E.5.

depending upon the anode voltage and the type of tube, is between about 0·1 and 0·4 mm. per volt. The spot diameter is from $\frac{1}{4}$ to 1 mm., depending upon the anode voltage and the type of tube, and can be made of so small a size that even 400 line rasters have sharp definition. The fluorescent screen is made from finely grained materials and has no noticeable halo distortion. The material used (No. 17 in the table) has, besides its particularly high efficiency with low excitation and a colour which is pleasing to the eye, sufficient secondary emission in proportion to the primary electrons to ensure that no appreciable screen charges occur. The secondary electrons are drawn off by the anode, which has sufficient attractive effect at the surface of the screen

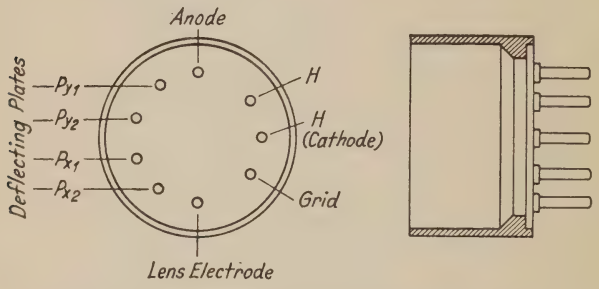

FIG. 34.—The arrangement of the pins on the socket of the author's tube as seen from below.

for this purpose. The distribution of the leading-out wires in the tube socket is shown in Fig. 34. An un-retouched photograph of a television raster obtained on the tube shown in Fig. 33 is seen in Fig. 35. The exposure time for this photo was about half a second, so that although the lines are obviously separate, they can hardly be distinguished from one another with a 250 line raster. The photograph shows the evenness of the illumination and the almost perfect rectangularity of the picture format. A good format is obtained by accurate adjustment of the magnetic picture deflection and is of great importance for truly distortionless picture reproduction. Moreover, with a good format, a window or proscenium, which limits the picture area, is redundant. The sharp edges of the raster, and the good spot sharpness right up to the edge, prove that the time base, to be described in a later chapter, is operating correctly. Further, the photograph

PLATE XIII

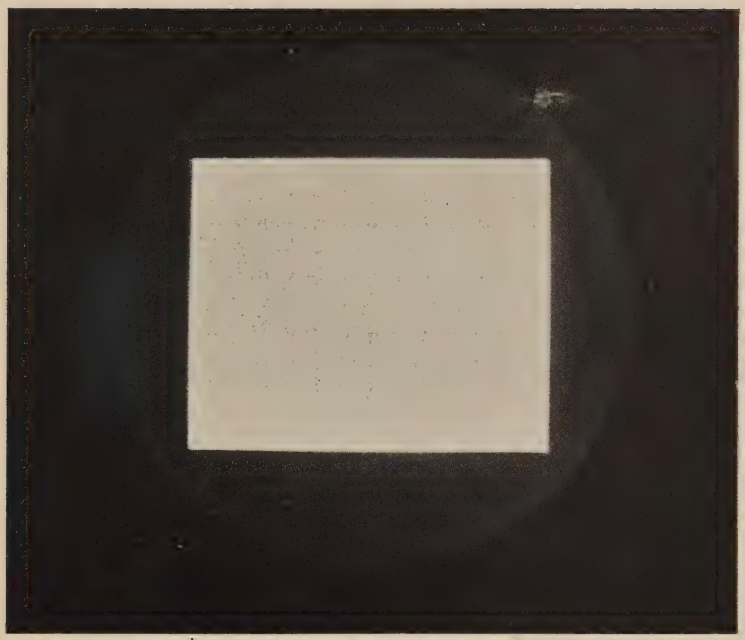

FIG. 35.—Photograph of the raster obtained on the high vacuum tube shown in Fig. 33.

[*To face p* 42.

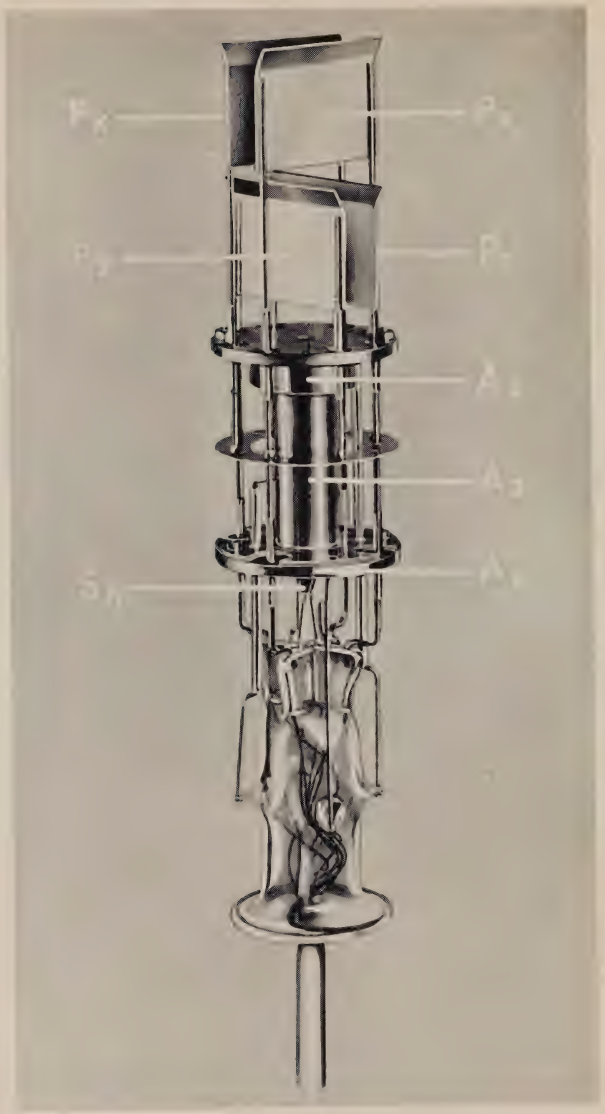

FIG. 36A.—The electrode system of the Cossor television cathode ray tube shown in Fig. 36B.

To face p. 43.

FIG. 36B.—Cossor Cathode Ray Tube for Television. This tube provides a brilliant black and white picture, 10 inches long × 8 inches in height.

[*To face p.* 43.

(Fig. 35) shows the freedom from halo and the great contrast in the illumination between the raster area and the remainder of the screen which is only obtained with high-vacuum tubes. The limit of contrast is, moreover, still further improved by blackening the bulb in order to reduce light reflection.

The electrode system of a Cossor television tube with four deflecting plates is shown in Fig. 36A, and a view of the whole tube is shown in Fig. 36B. In this tube an extra positive lens electrode is used and the lens system is thus a compound one, three separate potentials being required for the system. This, however, involves no difficulty as only an extra fixed resistance and condenser, costing but a few pence, are required for its operation.

The potentials used on the three anodes of the lens system are in the following ratio :—

Anode 1 (nearest cathode) approx. 1/15 Va 3.

Anode 2 (cylindrical anode) approx. ¼ Va 3.

Anode 3 (nearest screen) Va 3.

The potential applied to the third anode is normally 4,000 volts.

The bias potential is approximately equal to the first anode potential, and a peak voltage swing of approximately 25 volts is required to modulate the tube fully, *i.e.*, from extinction to the condition of maximum brilliance, without loss of focus. The modulation is applied to the first anode as well as to the grid. If the modulation is to be applied to the first anode also, it is necessary to insert a resistance between the potentiometer R5 and the anode and to join the end of the resistance nearest to the anode to the grid, *viâ* a condenser of about 0·25 MF (see Fig. 39B). This condenser should be able to withstand, say, 500 volts. In common with all other makes of cathode ray tube, the focus deteriorates if the brilliancy becomes excessive, but the double modulation method adopted considerably reduces this tendency.

The deflectional sensitivity of the Cossor tube is approximately $\frac{800}{\text{Va } 3}$ mm. per volt and the screen diameter is 30 cms.

In the case of the Cossor tube the part of the beam which is imaged on the screen is not, as in the case of the author's tube, the cross-section of the beam at the point where it passes through the first hole in the lens system, but a virtual image of the beam as it exists at the cathode surface.

Another difference between the two tubes is that the Cossor tube has two sets of deflecting plates. The question of the choice of magnetic or electrostatic deflecting arrangements in the picture-change direction is, to a certain extent, governed by the arrangements in the remainder of the circuit, in particular by the type of time base and whether its output is applied to the tube with or without previous amplification.

The question of alignment is of very great importance in the construction of cathode ray tubes exactly as in optics, for, should one electrode be so arranged that the beam does not lie normal to its surface, astigmatism will be introduced and the spot will be drawn out into a line. As a matter of fact, practically all ordinary optical effects may be reproduced in an electron-optical system. For the above reasons, the question of mechanical rigidity has received considerable attention.

Not only do the deflecting plates act as cylindrical lenses when arranged to be fed in an asymmetric manner, thus producing astigmatism for wide angle deflections, but they function as though they were prisms when deflecting the beam, whether symmetrically fed or not.

The screen provided gives a very satisfactory black and white picture of intense brilliance.

The Cossor cathode ray tube is fitted with a special form of base and socket which are so arranged that the connecting wires may be soldered to the socket and the latter pushed on to the base after the tube has been fitted into position in the mounting provided to support it. The socket and base are fitted with projecting lugs which make it impossible for the socket to be incorrectly attached to the base.

The various potentials required for operating either of the cathode ray tubes described herein are best obtained from the mains apparatus which is described in the following chapter.

On first fitting up the author's tube for service, the heating current must be gradually increased until, after some two minutes, it will have reached the predetermined value. Further regulation of the heating current is unnecessary. With A.C. heating one must see that that end of the filament which is connected to the equipotential surface of the cathode is joined to the earthy side of the heater circuit. During the initial heating period and afterwards, it is necessary with either tube to see that the light control

electrode is always sufficiently negative to provide only just the required brilliancy. Lower values of bias should be avoided, not only for the reasons already discussed, but also in order that the screen material need not be unnecessarily loaded. The deflection supply sources should be brought into service before the tube begins to function, thus the large ray energy will always be distributed over a part of the screen surface. Even if all the mains potentials are switched on at the same time the above-mentioned conditions can be fulfilled if the temperature inertia of the cathode of the tube is made greater than that of the indirectly heated valves in the remainder of the equipment.

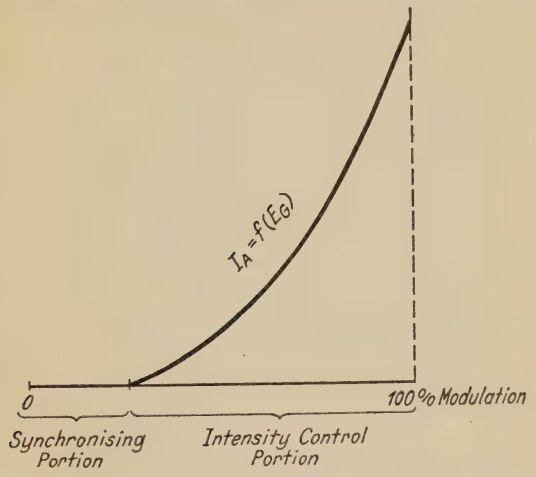

FIG. 37.—The adjustment of the brilliancy characteristic of the author's cathode ray tube.

In contrast with the method of using amplifying valves, when using cathode ray tubes with deflecting plates for measuring purposes, it is usual to connect the positive pole of the anode supply to earth in order to prevent those parts of the circuit joined to the deflecting plates from having high potentials to earth. The earthing of the cathode, particularly with a complete television receiver, has, however, many advantages. For example, with this method of operation, the mains units for the different parts of the circuits may be made more compact. By earthing the cathode, the coupling condensers for the time base voltage or the time base output transformer must be insulated for high

potentials, but, on the other hand, a number of the component parts of the receiver described here may have sensibly lower insulation.

The bias control for the light control electrode, or grid, is adjusted so that when the transmitter is sending a dark signal, anode current just begins to flow, as shown in Fig. 37. The pictures in Fig. 38 show the effect of the choice of bias voltage on the picture reproduction. The final stage of the radio receiver and the rectifier must be correctly matched to the cathode ray tube so that when a bright signal is transmitted (100 per cent. transmitter modulation) the bias voltage change brings the working point to the highest anode current obtainable with good spot definition.

PLATE XVI

FIG. 38.

(*Above*) Insufficient bias on the modulating grid.
(*Centre*) Correct bias.
(*Below*) Too much bias.

[*To face p.* 46.

CHAPTER III

THE MAINS SUPPLY APPARATUS

(Power Unit)

THE television tube requires, for its operation, an anode voltage of 3,000 to 4,000 volts, while for particularly bright pictures one uses from 5,000 to 7,500 volts. Furthermore, as already described in the last chapter, one or more additional positive voltages for the lens electrodes of the tube are necessary, and these must be capable of accurate adjustment to a specified value in order to produce the best possible focus of the spot. For the author's tube, where only one voltage is necessary, the adjustment of this voltage must be so arranged that values between about one fifth and one third of the main anode voltage are available. A steady voltage adjustment is also necessary to provide the negative bias for the light control electrode. This bias voltage control must be so arranged that negative voltages of 100 to 150 volts can be obtained. Besides these voltages, a heating current source which must be able to deliver currents of 0·5 to 0·6 ampere at a potential of about 4 volts is necessary for the author's tube, or 1·0 ampere at 2 volts for the Cossor tube.

A. The Circuit

For television reception, only the above-mentioned voltages and currents need be obtained from the A.C. mains supply unit. The question of the D.C. supply for the other parts of the receiver can be disregarded for the moment, since the radio receiver and the time bases will have their own power supply units incorporated.

The relatively simple circuit shown in Fig. 39A provides all the necessary voltages and currents for the operation of the author's cathode ray tube, while Fig. 39B shows the circuit of the power supply unit for the Cossor tube and is described later in the book. All the D.C. voltages are well smoothed with the component values given and the condenser voltages specified here, and in the later circuits, are " test voltages."

The cathodes of the author's tubes are indirectly heated and are so arranged that the magnetic field due to the filament can have no

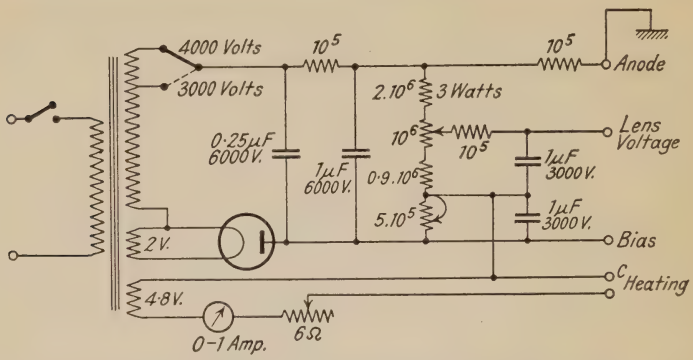

FIG. 39A.—The circuit of a particularly well smoothed mains supply unit for television tubes.

effect on the electron beam. The small field produced by the leads to the cathode, inside the tube, is compensated by looping

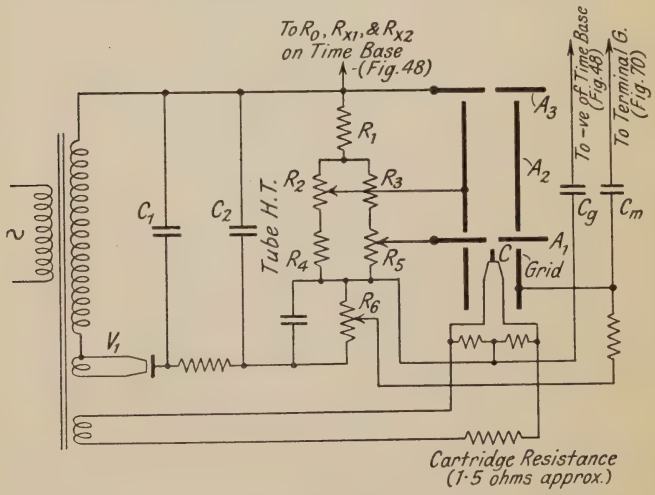

FIG. 39B.—Mains power supply unit for use with the Cossor cathode ray tube.

them. No observable effect due to the use of A.C. heating exists and it is only necessary to ensure that the terminal marked C in

PLATE XVII

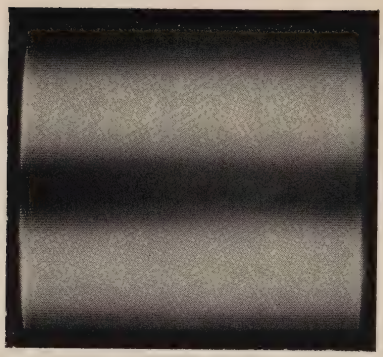

FIG. 40.—Effect on the raster of 50 cycle ripple from the mains power unit.

FIG. 41.—Lack of sharpness of the raster and picture detail due to incorrect lens focussing potential.

[*To face p.* 49.

Fig. 39A is joined to that contact of the tube socket which leads directly to the cathode of the author's tube. The effect of connecting the contacts incorrectly is shown in Fig. 40.

The use of the correct lens voltage has a great effect on the sharpness of the television picture. The photograph (Fig. 41) shows the lack of sharpness of the raster and picture detail obtained with an incorrect lens electrode potential. Focussing should preferably be carried out with a raster and not while a picture is being received, and the bias value should be so adjusted that the raster is relatively dark. If the voltage conditions are not altered by the deflection, the sharpness of focus remains good right up to the edges of the screen. Since, with the receiver described later on, the carrier frequency appears on the screen, if the intermediate-frequency modulation spots can be seen separately from one another, this fact may be used as a criterion of the quality of the point sharpness in the raster.

Special valves (Leybold or Cossor S.U. 2130), having anode and cathode led out at opposite ends of the tube, are used for the rectification of the high potentials. Moreover, the rectifying valve must have a mechanically stable cathode and the anode must be relatively distant from it, so that the cathode will not be destroyed by the powerful electrostatic field. Since the ray current of the cathode ray tube is small compared with the total current supplied by the high potential source (about 1 ma.) it is sufficient to make the transformer, rectifier and smoothing system of such a size that they can handle currents of just over 1 ma. It is recommended that the output of the rectifier and the quality of the smoothing be not increased above the values given for Fig. 39A, since the dangers of high potentials are thereby increased. The resistance in the high tension lead is inserted to limit the current in case of short circuits.

The circuit of Fig. 39A is obviously also useful for higher anode voltages if the values and insulation of the various parts are correspondingly altered. The circuit of Fig. 42 has proved to be of particular use for the higher anode voltages since, by the use of a voltage-doubling circuit, the voltage in each part of the circuit is reduced. Since, by means of the potential divider and the resistances R3 and R4, care is taken that the smoothing condensers in series with one another have their potentials equally distributed, the condensers may be made for half the voltage and

of double capacity, hence the space requirement is reduced. Of course the voltage-doubling circuit requires two rectifiers, but, here again, proportionally smaller types will be satisfactory. The resistances R1, R2 and R5 are limiting resistances. In contrast with the circuit of Fig. 39A, the cathode of the mains unit in Fig. 42 is earthed. In order to obtain good insulation of

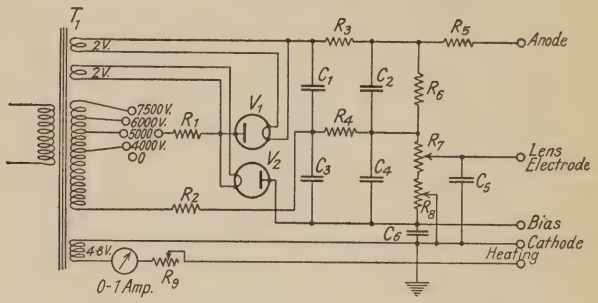

FIG. 42.—The circuit of a voltage-doubling mains supply unit for use with a cathode ray tube of the author's type when the filament of the tube is at earth potential.

the transformer winding without occupying too much space, it is essential to inform the manufacturer of the transformer whether the anode or cathode side of the circuit in Fig. 42 is to be earthed.

Parts List for the Circuit of Fig. 42.

R1	25,000 ohms.	1 watt
R2	25,000 ,,	1 ,,
R3	0·03 megohms.	1 ,,
R4	0·03 ,,	1 ,,
R5	10,000 ohms.	1 ,,
R6	7·5 megohms.	each 1 ,,
	(3 × 2 and 1 × 1·5 megohms.)	
R7	7·5 megohms.	3 watts
R8	0·2 ,,	1 watt
R9	6 ohms.	1 ,,
C1, C2, C3, C4	1 MF.	6,000 volts
C5	0·25 ,,	4,000 ,,
C6	2·0 ,,	1,500 ,,
V1	Leybold or S.U. 2130 (Cossor)	
V2	,, ,, ,, ,,	

Parts List for the Circuit of Fig. 42—continued.

T1 . Mains Transformer
Secondary, 2,750 volts . . . 5 ma.
Heater, 2 each of 2 volts . . 1·0 amp.

Each secondary winding to be insulated to withstand 8,000 volts to every other winding and to the core.

B. Mechanical Construction Details

The following points in connection with the mechanical construction of the power unit should be noted. If the anode is earthed, all the leads except the positive H.T. lead must be insulated. All parts should have an air spacing of about 1 cm. from earth-connected parts of the circuit. The potentiometer, the socket for the rectifier, the heater resistance and ammeter, the various terminals and the lens and bias voltage smoothing condensers must be mounted so that they are well insulated from earth. For the ammeter, an instrument with an insulated case is recommended. The rheostat for the heater must be arranged either with an insulated spindle or with a special knob which has a long insulator between it and the spindle to ensure that no danger exists in operation. If one does not wish to change to other anode voltages the voltage change switch may be omitted. If the cathode is earthed, only the anode lead need be specially insulated for high voltages. In the latter case less smoothing may be used.

Care must be taken, by grouping of the parts, that no interference due to stray capacity to the wires carrying high A.C. voltages can take place in the apparatus. This refers, in particular, to the transformer itself and to the leads to the rectifier. This point is very important since, for example, the synchronising circuits of the time base are very sensitive to such discharges.

The transformer, together with the other mains transformers, must be so arranged that their stray fields have no noticeable deflecting effect on the electron beam in the cathode ray tube. To reduce the danger of magnetic disturbances which produce a periodic shift of the television raster position, the greatest possible distance between the transformer and the tube (at least 40 cm.) should be allowed, and the iron cores should be suitably oriented so that the cathode ray tube lies along the plane of the cores. Fig. 43 shows the effect on the raster of a

particularly strong magnetic 50 cycle stray field in the cathode ray tube. Fig. 44 shows the characteristic distortion of the picture detail as a result of these disturbances. Before the final assembly of the receiver it must be tested to see whether stray fields are definitely avoided with the distances and positions which have been chosen for the transformers. An effective method of avoiding stray disturbances is to screen the transformer itself in a massive box. The mains transformer screen has to be rather large on account of the necessity for high insulation.

In order not to complicate further the construction of a television receiver the values of the component parts which have been found to be the best are given for the mains unit circuits of Figs. 39A, 39B and 42, as are those for the circuits of the other apparatus described in the following chapters. In many parts of the equipment considerable saving is possible, for example, in the smoothing circuits. In spite of the fact that all the values of the component parts are given, in order to ensure that the receiver shall be free from trouble, the values are sufficiently liberal to provide a reserve to cover later requirements.

With regard to the construction, it is recommended that the mains unit and the circuits in the following chapters should be built as separate or, at least, temporarily separate units, in order to permit of later variations or improvements without too much difficulty.

The mains unit for the Cossor cathode ray tube is shown in Fig. 39B. This unit is one in which the extra lens potential is provided. A small cartridge resistance of approximately 1·5 ohm (the actual value required is shown on the label round the neck of the tube) is used in place of the rheostat and ammeter, but the resistance value stated is, of course, intended to apply only when a specified heater potential (2 volts) is used.

Parts List for Fig. 39B.

V1	S.U. 2130 (Cossor) or Leybold Rectifier.	
C1	0·25 MF.	4,000 volts
C2	0·25 „	4,000 „
Cg	0·25 „	4,000 „
Cm	0·1 „	4,000 „

PLATE XVIII

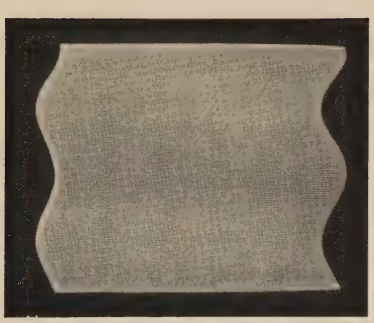

FIG. 43.—Effect on the raster of a superimposed 50 cycle deflection in the line direction. (For example, due to stray magnetic fields from the mains transformers when placed too close to the tube.)

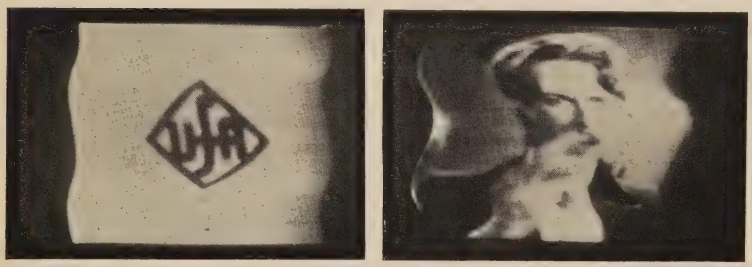

FIG. 44.—Distortion of the picture content due to 50 cycle interference on the raster.

[*To face p.* 52.

Parts List for Fig. 39B—continued.

R1	3	megohms.	3 watts
R2	2	„	Potentiometer
R3	1	„	1 watt
R4	1	„	1 „
R5	2	„	Potentiometer
R6	0·5	„	„
Modulating resistances	3	„ each	1 watt

CHAPTER IV

THE TIME BASES

For the production of the television raster two time bases are necessary, as explained in Chapter I. The television time base apparatus is thus always built as a double time base. The line and picture portions are always operated from the same mains unit, and mutual interference is avoided by means of decoupling arrangements, screening and suitable disposition of the component parts. For the construction of the double time base there are various possible arrangements which will be indicated in this chapter. A form of this apparatus which has, in the course of research work, proved to be of special value, will be described in detail.

A. The Production of Time Bases

The schematic diagram of a time base is shown in Fig. 45. The condenser C becomes charged from a source of current having a voltage E, *viâ* the resistance R. In parallel with the condenser is the discharge circuit which, in the example shown, takes the form of a neon lamp. As soon as the voltage across the condenser C reaches the striking voltage of the neon lamp, the latter fires and discharges the condenser to the extinction potential. The discharge of the neon lamp ceases and the condenser is again charged until finally the striking voltage is again reached, and so on. In this way a time base potential is produced across the condenser. In order to avoid distortion of the reproduced picture, it is necessary that the potential across the condenser shall rise linearly with respect to time. In order to obtain a good

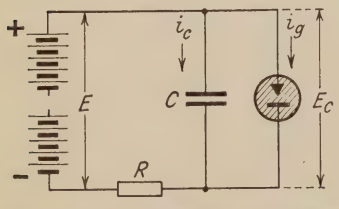

Fig. 45.—Schematic diagram showing the principle of operation of a time base.

time base wave-form, however, other methods are advisable. For example, the resistance R may be replaced by a valve which will give the same anode current independently of the value of the anode voltage. A screen-grid valve operating over the straight portion of its characteristic or a triode, having a tungsten cathode and operating in a saturated condition, possess the necessary property. The same charge always flows into the condenser in a given time and good linearity is thus ensured. This method is suitable if the voltage across the condenser is applied directly to the deflecting system, so that it is desirable that the time base potential swing shall be the highest possible percentage of that provided by the source of current. The other, more simple method is to choose a neon lamp having a striking-extinction potential difference which is small compared with the potential of the source. In this way the range of voltage swing is so small that the bend in the charging curve of the resistance-condenser unit is unimportant, and a linear voltage swing is, in practice, obtained. In order to provide sufficient output the use of an amplifying stage is, however, necessary. In the apparatus described herein this second method is adopted, but a time base employing ordinary high-vacuum valves instead of gas-filled lamps or valves is also described which may, if desired, be incorporated in the equipment and with which no extra amplifying stages are required.

With a given striking-extinction potential difference of the discharge circuit, the frequency of the time base depends upon the value of the condenser C and upon the charging current, *i.e.*, with a constant potential of the current source it depends upon the value of the charging resistance R. Since one must always take into account variations of the potential of the lighting mains and its effect in producing changes in the potentials obtained from the mains unit, the synchronisation must be sufficiently strong to prevent variations of time base frequency.

The best working conditions are obtained with the aid of neon stabilisers (Marconi Stabilovolt) which will keep the high tension voltage supply to the time base at a constant value. The stabilisation of all the voltages in the time base is, however, not economical because of the high currents required for the operation of the stabiliser at the necessarily high rectified voltage. If stabilisa-

tion is required, it is sufficient to keep the high tension at a few hundred volts (in the circuit described, 400 volts) on the one hand and, on the other, to keep the thyratron grid voltage constant so as to obtain constancy of the time base frequency. Since only very small currents are required for the time base and for the thyratron grid voltage, it is satisfactory to use low current glow lamps for stabilisation.

Besides the time base amplitude, linearity and frequency, the discharge time is of importance, as already explained. This time is fixed by the capacity of the condenser and the resistance of the discharge circuit, if the inertia of the final amplifying stage and of the compensating circuits are neglected. The resistance of the discharge valve and the other resistances in this circuit chiefly determine the discharge time. Two discharge current wave-form oscillograms are shown in Fig. 46. The upper one is the curve obtained with a resistance of about 5,000 ohms and a capacity of 1,000 mmf., while the lower one is the curve obtained without any added resistance. In accordance with the point of view discussed in the first chapter, the fly-back, or discharge time of the picture and line time bases are so arranged, by suitable adjustment of the discharge circuit values, as well as those of the amplifying stage, that the fly-back time is not greater than the time occupied by the synchronising gaps, or signals, sent out from the transmitter.

In order that the time base at the receiver shall correspond exactly in frequency and phase with the equivalent values at the transmitter, the discharge must be controlled with very great accuracy by the transmitter. So as to avoid damaging the picture sharpness or definition, it is necessary to ensure that the time of commencement of each line shall be accurate to within 10 per cent. or, at the outside, 30 per cent. of the time occupied by one picture element. With the present standard of transmitter definition (180 lines) the above-mentioned requirement means that the variations in the time of completion of the discharge of the time base between successive lines can only just exceed 10^{-7} seconds.

With regard to this small tolerance, only those gas discharge tubes, which work particularly smoothly on account of their construction, or arrangements with high-vacuum tubes can be used.

PLATE XIX

FIG. 46.—Time base condenser discharge current (above) with and (below) without a resistance in the discharge circuit. (Oscillogram time $\frac{1}{800}$th second ; C = 1,000 mm.F.)

[*To face p.* 56.

B. Self-running Controlled Time Bases or Distant Operated (not Self-running) Time Bases

As a rule the receiver will be arranged with a self-running time base of the type shown in Fig. 45, in which the frequency of the circuit is brought into good agreement with the transmitter time base frequency. Accurate synchronism is brought about by the impulse from the transmitter, just before the time base would naturally discharge of its own accord, the impulse so far reducing the required striking voltage that the discharge occurs before the natural time.

The above-mentioned method will be used in the time base circuit to be described below. The other method is one in which the condenser discharge is completely controlled by the synchronising impulse from the distant transmitter, and in which the time base does not function of its own accord.[1] Distant control is most easily carried out by the arrangement shown in Fig. 47. The short time pulses at the end of each line and the longer pulses at the end of each picture must be fed to the grid of the discharge valve E, of the diagram Fig. 47, in such phase that a positive potential is applied. By correctly adjusting the value of the capacity C and the impedance of the discharge valve circuit, the discharge can be made to occur in a time which is only a few per cent. of the time base period, *i.e.*, of the total time occupied by one line and one discharge, or fly-back. The condenser is charged through the valve V or by means of a resistance, as already described. Since the synchronising impulse from the transmitter accurately agrees with the wave-form shown in the

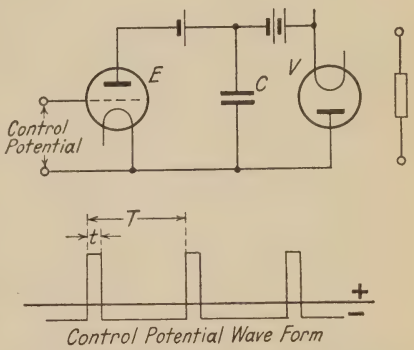

FIG. 47.—Typical valve circuit for a distant controlled time base.

[1] M. von Ardenne, "Zur Fremdsteuerung der Strahlbewegung beim Fernsehen mit Braunschen Rohren," *Zeitschrift für technische Physik.*, 1934, Vol. 15, No. 2.

lower part of Fig. 47, the distant control method is obtainable without difficulty. Since the fly-back, or condenser discharge, is controlled by the synchronising signal, the cathode ray beam at the receiver is forced to follow and to duplicate the picture scanning as it appears at the transmitter. With this exceedingly simple time base the only requirement is that the charging current shall be correctly adjusted so that the picture format can be brought to the desired size without interference with, or by, the synchronising signal. Therefore, by adjustment of the charging current it is possible to reduce the size of the picture format by day, so that greater brilliancy is obtained, while a larger format, with correspondingly lower brilliancy, may be used at night.

When the supply voltage for the time base charging circuit is of a suitable value, one may arrange that, if the transmitter is switched off, or if the discharge control fails, the cathode ray beam will be driven off the picture surface, thus avoiding burning of the screen. Alternatively, the spot may be automatically blacked out for the same purpose. The correct amplitude of the synchronising impulse is, of necessity, obtained when the receiving apparatus has the correct values for its component parts and when the output voltage of the radio receiver is so adjusted that a contrasty picture is received. Field strength variations produce changes in the discharge time, *i.e.*, they bring about small variations at the ends of the picture and of the lines together with variations in contrast.

In contrast with this, the use of self-running time bases have the following basic disadvantages :—

The synchronised time base frequency is not definitely fixed. It can also become a whole number ratio of the required frequency if the time base is incorrectly adjusted. The control of the self-running time base is made more difficult by the necessity for approximate agreement with the synchronising signal, particularly as the effect on the picture of incorrect adjustment by the layman will not, at first, be recognised as such. In spite of this, the time base to be described is of the self-running type, since later researches have shown that good operation with distant control time bases, which are unable to operate without that control, is difficult to develop experimentally and, moreover, such time bases are more sensitive to interference which can only be disregarded when the

transmitter field strength is very great or when a good amplitude filter is used.

C. The Time Base Discharge Valve and its Control

The discharge of the time base condenser is, as a rule, brought about by means of neon lamps or thyratrons or by ordinary high-vacuum valve circuits. The neon lamp, particularly in the form in which the control electrode is outside the bulb, is out of the question except for the most simple form of television work.

For the construction of an efficient receiver neon lamps are not to be recommended on account of the relatively high synchronising voltage required. As a rule, a so-called thyratron is used for the synchronising of the time base potential. These valves, which are also referred to as gas discharge triodes, are gas-filled valves with hot cathodes in which the discharge is controlled by means of an electrode between the anode and the cathode.[1]

The striking-extinction potential difference may be varied, between wide limits, by the application of negative bias potentials of varying amplitude to the control electrode, or grid. The constant bias for the grid is so adjusted that the required amplitude of time base sweep is obtained, *i.e.*, the correct length of line is obtained on the cathode ray tube screen, and the synchronising signal is superimposed upon this bias; this applies a high positive potential to the grid for a short time.

In the interest of a longer useful life, the thyratron must not be operated with too high anode voltage or with too much anode current. Since, during the instant of fly-back, fairly high currents flow in the control grid circuit, any resistance in that circuit must not be too high.

In addition to gas discharge valves, high-vacuum valve discharge arrangements are of considerable importance in television reception. High-vacuum valve circuits operate in a much more stable manner than do those containing gas discharge valves, especially at the higher frequencies. For this reason high-vacuum discharge circuits are rapidly replacing gas discharge devices for television reception in industrially manufactured receivers.

[1] For a full investigation of the method of operation of these valves see A. Glaser, "Die physische Grundlage der Gittersteuerung von Gasentladungsgefässen" ("The Physical Theory of the Grid Control of Gas Discharge Tubes"), *Zeitschrift für technische Physik.*, 1932, Vol. 13, No. 2, p. 549.

A newly developed form of high-vacuum time base for television was described by an English firm (A. C. Cossor Ltd.) some

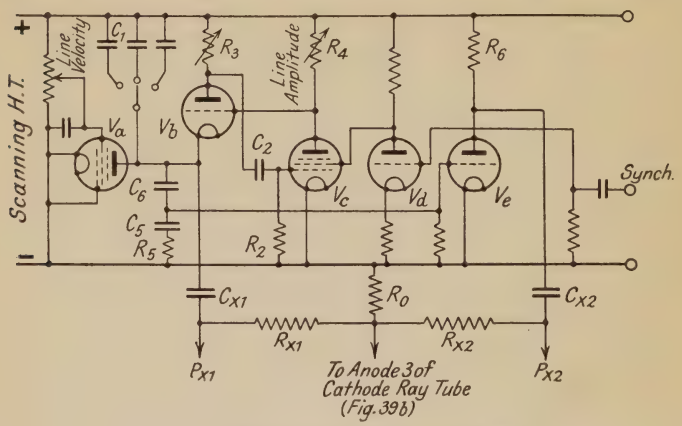

FIG. 48.—High-vacuum valve time base.

time ago.[1] In this apparatus, the circuit of which is shown in Fig. 48, the condenser C1 is charged by the pentode valve Va,

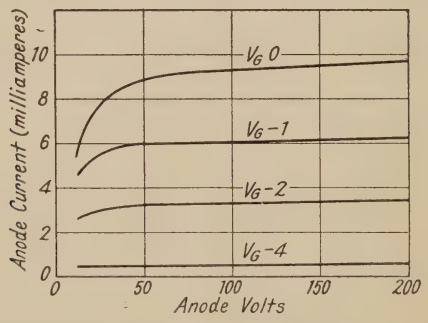

FIG. 49.—Anode volts—anode current characteristic curve of a pentode valve. (Cossor MS/PEN with 100 volts on the screen.)

operating over the linear portion of its anode volts-anode current characteristic.[2] This characteristic is shown in Fig. 49 and,

[1] A. C. Cossor Ltd. and O. S. Puckle, British Patent Specification No. 419298, 1933.
L. H. Bedford, M.A., and O. S. Puckle, "A Velocity Modulation Television System," *Journal Inst. of Elect. Engineers*, July, 1934, Vol. 75, No. 451.

[2] M. von Ardenne, Fernsehen, 1932, Vol. 3, No. 4.

provided the anode voltage is not permitted to fall to the bend in the curve, the anode current is substantially independent of the anode voltage. The charging current (anode current) is controlled by means of the potentiometer R1.

Reverting to Fig. 48, the action of the discharging device is as follows: The gas discharge triode is here replaced by two high-vacuum valves, which, however, together cost less than one thyratron. Of these two valves Vb, a triode, is the actual discharging valve, while Vc, normally a pentode, is used to control the valve Vb.

When the condenser C1 (of a value selected to suit the number of lines) is totally discharged the full positive potential appears on the anode of the valve Va, and therefore on the cathode of Vb, which is, for the moment, at the same potential as its anode.

The second valve of the discharge pair Vc is at zero grid

Parts List for Fig. 48.

Va, Vc	MS/PEN	(Cossor)
Vb	MP	,,
Vd, Ve	MHL	,,
C1	0·0005 to 0·002 MF.	1,000 volts
C2	0·001 MF. approx.	350 ,,
C5	Approximately 20 times C6.	
Cx1, Cx2	0·1 MF.	500 ,,
R0	1 to 3 megohms	1 watt
R3	1,000 ohms.	Potentiometer
R4	100,000 ,,	,,
R6	100,000 to 150,000 ohms.	5 watts
Rx1, Rx2	2 to 10 megohms.	1 watt

potential, with the result that its anode, and consequently the grid of Vb, is in the most negative condition. Since the anode resistance of Vc is high, it is quite possible for the grid of Vb to be brought to a potential 300 or 400 volts negative, or even higher, depending upon the potential existing across the positive and negative supply lines.

When the condenser commences to charge, the lower plate falls in potential and carries the cathode of Vb with it. As the potential of the cathode becomes more negative, it approaches that of the grid and, when it reaches a potential which is a few volts positive with respect to the grid, anode current commences

to flow. This anode current naturally causes the potential on the anode of Vb to fall, and a negative pulse is accordingly fed to the grid of Vc, *viâ* the condenser C2 and the resistance R2. This pulse reduces the anode current in the valve Vc, and consequently increases the anode potential of Vc, so that the grid of Vb will become more positive. The increase of grid potential increases the rate of discharge of the condenser and provides a further increment of negative charge on the grid of V3, so that the effect is a cumulative one and therefore a very rapid change from the charging to the discharging condition is possible.

When the potential across the condenser has fallen, as a result of the discharge, to such a value that the anode current of Vb commences to fall, a positive pulse is fed to the grid of Vc, thus making the grid of Vb become negative and stopping the discharge. By making the resistance R3 variable, the rate of discharge of the condenser, and the rapidity with which the circuit changes from the charging to the discharging condition, and *vice versâ*, may be controlled. When R4 is made variable the potential to which the condenser is charged may be controlled.

A synchronising valve may be used to function as an amplitude filter, and this operation is performed by the valve Vd. A further difference between this time base and that developed by the author lies in the method of obtaining the balanced output which is essential with high-vacuum cathode ray tubes

Instead of using a paraphase system, the time base employs a special amplifier in which the high-frequency components of the saw-tooth wave-form are retained, in spite of the high anode resistance employed (about 100,000 ohms). The effective anode load of the valve Ve at low frequencies is equal to the value of the anode resistance R6, in parallel with the impedance of the triode Ve. This effective load is shunted by the stray anode capacity of the valve and, therefore, the high-frequency components are not amplified to so great an extent as those of lower frequency. By making the time constant C5, R5 equal to that of the effective anode load, shunted by the stray capacity, the circuit is compensated for these higher frequencies.

The method of coupling the balancing valve to the anode of the charging valve is of interest. If the valve Ve has, for example, a gain of 20, the potentiometer C6, C5 is designed to reduce the potential applied to the grid by a ratio of 20 to 1. Hence the

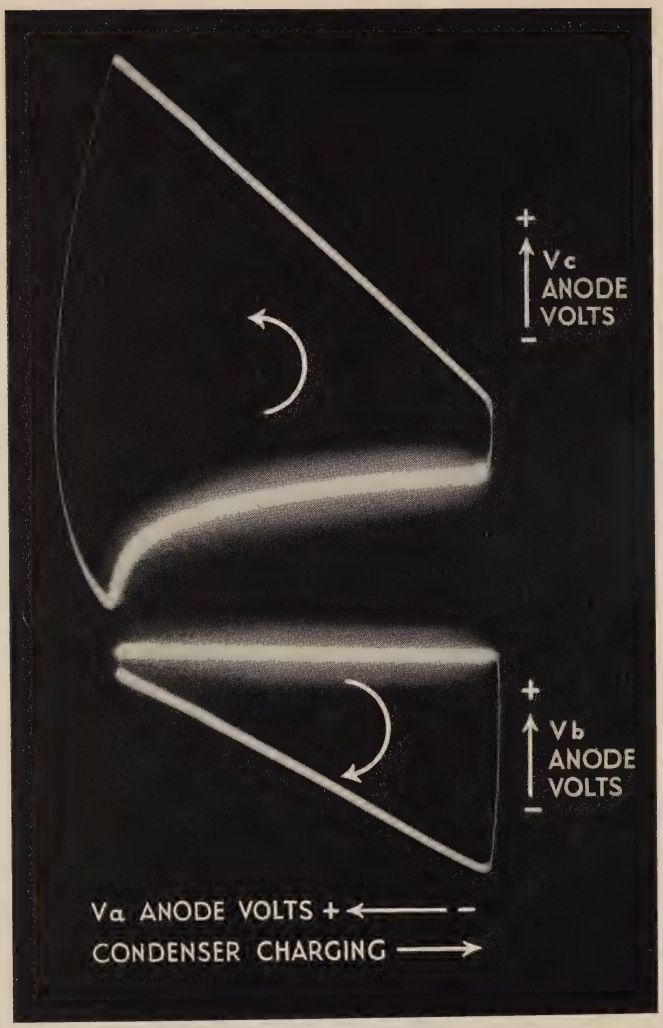

FIG. 50.—Cycle diagrams explaining the operation of the Cossor hard valve time base. (*See* Fig. 48.)

[*To face p.* 63.

potential appearing on the anode of Ve is equal in amplitude, and 180 degrees out-of-phase with the potential on the anode of Va. The potentials on the anodes of Va and Ve are then fed to the horizontal deflecting plates Px1 and Px2 of the cathode ray tube to produce the line deflection.

The picture deflection may be produced by a similar time base, in which the value of the condenser C1 is altered to suit the picture frequency or, alternatively, a gas discharge triode time base may be adopted. Whichever form of time base is adopted for the picture deflection, both time bases may be synchronised from the same valve Vd in Fig. 48.

During the development of the time base some cycle diagrams were obtained on a cathode ray oscillograph in order to demonstrate the operation of the time base. These diagrams are of particular interest and are reproduced here for the first time.

Fig. 50 shows the cycle diagram of the potential on the anode of Va, plotted against the anode potential of Vc. In these diagrams the anode potential of Va is plotted horizontally, decreasing from left to right, *i.e.*, the potential across the condenser increases from left to right. The upper diagram shows that the change from the charging to the discharging condition is extremely abrupt and the later 45 degree slope, due to the grid and cathode potentials of Vb being locked by grid current, is very clearly illustrated. The abrupt change to the charging condition is also very clearly seen, and the return of the grid of Vc to the zero grid condition during the next charging period is also made evident by the increase in anode potential.

The lower diagram in the figure shows the relationship between the potential on the anode of Va (horizontal) and the anode of Vb (vertical). These diagrams merit thorough study as they are of extreme interest and much can be learnt from them.

D. The Amplification of the Time Base Output Voltage

With the time base operating with the gas discharge tube, the striking-extinction potential difference of the discharge valve is small compared with the supply potential to the time base, and it is necessary to amplify the output voltage by means of an additional stage. On the other hand, the high-vacuum valve time base already described does not require further amplification of the output as this is already done by the balancing valve. A

balanced deflecting voltage is relatively easily obtained with an additional amplifying stage. For an economical time base it is necessary that the greatest possible time base voltage should be obtained with the lowest possible supply voltage. As the author has shown elsewhere,[1] this is obtainable with suitable valves for the amplifying stage, with anode voltages of some 100 volts, almost 80 per cent. of the supply voltage being obtainable as output, without distortion. In comparison with this, in the absence of amplification, and when using a constant charging current, 50 to 60 per cent. at the most is obtainable as output. If one considers that in the time base to be described the maximum output is doubled in the amplifying stage, the advantage is obvious. With magnetic deflection, for which a deflecting current is obviously necessary, the insertion of an amplifying stage is almost essential. This is also obvious if balanced deflecting potentials are to be obtained *viâ* a transformer.

E. The Circuit of a Double Thyratron Time Base

The circuit of a double time base arrangement for electrostatic line deflection and magnetic picture deflection, including the amplitude filter for the synchronising circuit which will be described in the following chapter, is given in Fig. 51, together with the values of the component parts. The mains unit for both time bases is shown on the left. In order to use the whole of the screen of large television tubes even at the highest anode voltages (5,000 to 7,000 volts), a proportionally high supply voltage of about 1,700 volts is provided for the time base. In order to permit of further changes being made, if required, the mains unit is not combined with the mains unit of the apparatus to be described in the following chapter. In this connection it must be vigorously pointed out that by reduction of the anode voltage of the time base and by combining the time base mains unit with that of the picture and sound receiver, the installation can be substantially cheapened.

The time base supply can be reduced to about 300 to 500 volts, even without making the deflection fields, which are produced by the time base, appreciably smaller than with the circuit of Fig. 51. Furthermore, instead of the above described push-pull stages,

[1] M. von Ardenne, " Die Kathodenstralröhre," *l.c.*, p. 132.

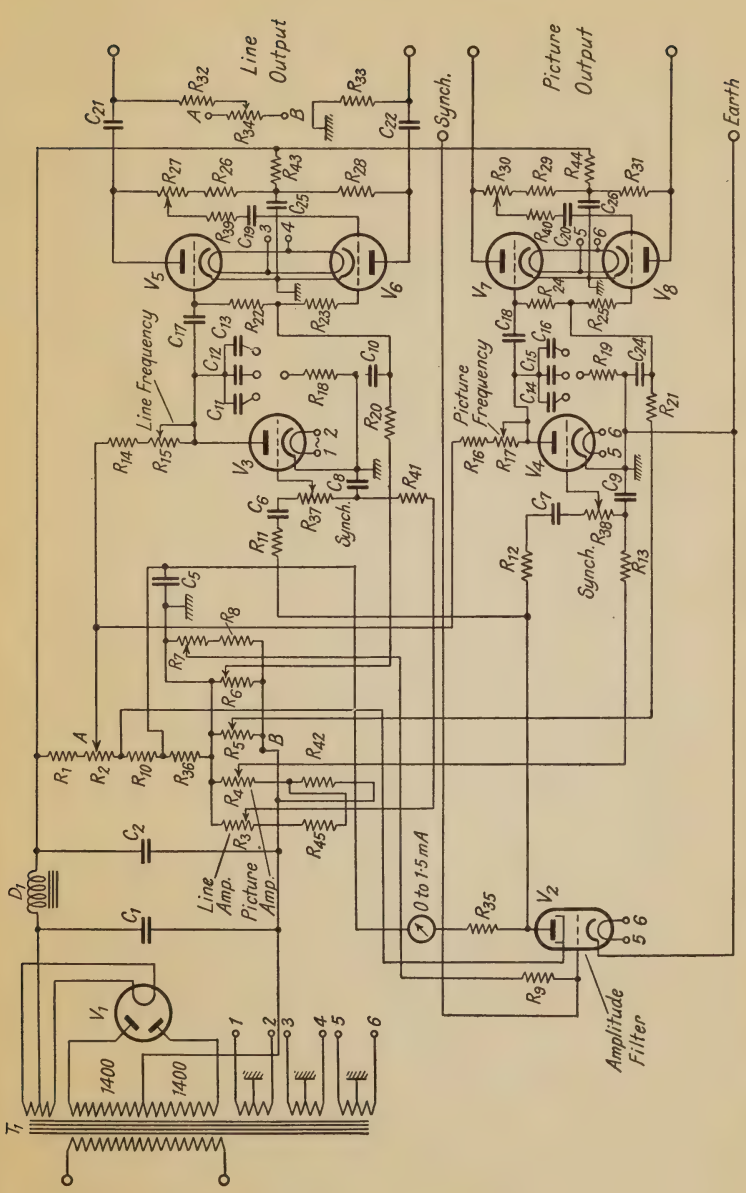

FIG. 51.—Circuit of a double-time base with push-pull output stages and incorporating an amplitude filter. This time base is intended to supply potentials and currents for electrostatic line deflection and magnetic picture deflection.

one can employ a simple high-gain stage for the time base potential amplifier. For this purpose, it is necessary to use a potential transformer in the time base, whose transformation ratio is so chosen that time base potentials with an amplitude of over 1,000 volts can be obtained. A limit to the potential transformation ratio is introduced by distortion of the originally linear slope of the time base characteristic, together with critical attenuation of the higher harmonics of the time base, which result in an increase of fly-back duration time. The frequency range over which such a transformer must function without phase and amplitude

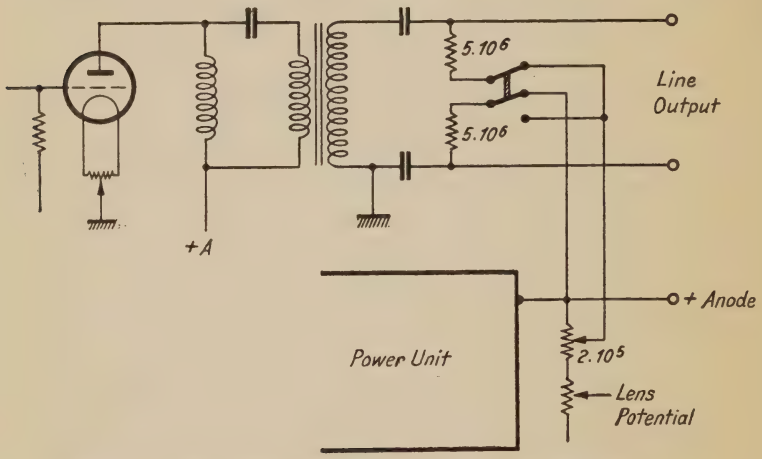

FIG. 52.—Alternative arrangement, using a transformer in the time base output circuit.

distortion is, from the time base traverse frequency to about twenty times this value. Either the transformer values must be so dimensioned, or the circuit must be damped (preferably by means of useful damping, *i.e.*, low valve impedance), that especially the lower harmonics of the time base frequency will be transmitted without noticeable phase change, as otherwise the slope of the curve will be distorted. The combination of a special transformer of suitable dimensions with a high-gain three electrode amplifier has proved satisfactory in research work. Fig. 52 shows the circuit for transferring the line time base potential to the deflecting plates, *viâ* a transformer. The connections to the deflecting plates are taken through relatively small capacities,

which must be insulated for high voltages when the cathode of the cathode ray tube is earthed. One must take care that the electron current from the deflecting plates of the cathode ray tube is provided with a return path to the anode, *viâ* resistances of high value. The switch and the additional voltage divider in the mains unit are shown in Fig. 52 which gives values suitable for smoothing ; these must, of course, also be insulated for high voltage. Even in the picture portion, a simple output stage is sufficient if iron cores with pole shoes are used for the deflecting coils so as to reduce the magnetic leakage and if a high impedance output valve is used so as to provide a suitable time constant $\frac{L}{R}$. In the double-time base shown in Fig. 51 and described in the following lines, the above-mentioned suggestions have been omitted since many points of difficulty arise.

In the circuit (Fig. 51), the time base charging condenser is given three values, of which any one may be used, for carrying out researches with various line and picture frequencies.

The two time base condensers are charged *viâ* high resistances in order to produce the line and picture scanning potentials. Safety resistances are connected in series with the charging resistances in order to limit the current, since this would rise to a value which might be dangerously high from the point of view of tube life, on account of the low impedance of the thyratron, should faulty operating conditions exist. As shown in Fig. 51, only a part of the voltage across the voltage divider R1, R2, R10, R36, is used for charging ; this charging potential is of the order of 400 to 500 volts. The bias voltage for the two time base discharge tubes is, with the values given in the figure, adjustable within the range found necessary in order to provide the desired picture format on the screen of the cathode ray tube. The anode voltage, of only a few volts (6 volts), the screen voltage (40 volts approx.) and the bias voltage for the amplitude filter are drawn from the potential divider. In order to secure freedom from trouble in operation, the grid voltages for the thyratrons are separately smoothed. Good smoothing is very important in the case of the line time base.

The synchronising potential appearing at the output of the amplitude filter passes, *viâ* condensers, to the synchronising potentiometers in the grid circuits of the gas-discharge valves.

Because of grid-current and, in particular, in order to obtain a short time constant for the synchronising circuit, these potentiometers must not be of too high a value of resistance. When the time base is required for normal service rather than for research, the circuit can be somewhat cheapened by omitting the resistances R11 and R12 and by using fixed resistances in place of the potentiometers R37 and R38.

F. The Correct Adjustment of the Synchronising Impulse

For good picture reproduction it is essential that the synchronising impulse at the receiver should have a definite amplitude. If the synchronising effect due to a small impulse is too small, the charging resistance must be very accurately set, and small unavoidable supply voltage changes will be sufficient to interfere with the line and picture synchronisation. The characteristic appearance of badly synchronised pictures is shown in Fig. 53. In the right-hand picture, the picture time base is out of phase and the picture synchronising space is seen as a black bar across the picture. The fly-back lines can also be clearly seen, but when the time base is in phase these are blackened out, especially where they pass through the picture synchronising space.

With a gradual increase of the synchronising voltage, the synchronising effect at last becomes so great that, even with strong supply voltage fluctuations, the system does not fall out of synchronisation, and the picture then remains stable for long periods of time. The appearance of the picture, with correct adjustment of the *amplitude* of the synchronising impulse, is shown in Fig. 54.

With a powerful synchronising signal at the receiver, the charging resistance, and therefore the charging current, may be varied to a certain extent without causing failure of the synchronisation. The change of charging current, within small limits, introduces into the picture only a change in the phase of the time base potential. Two typical phase conditions for the line time base are shown in Fig. 54. The left-hand picture shows the synchronising impulse at the right-hand edge of the picture, as is evident by the dark zone, while at the top of the same picture it disappears behind the picture and appears again on the other side. Only when the fly-back is behind the picture is the

PLATE XXI

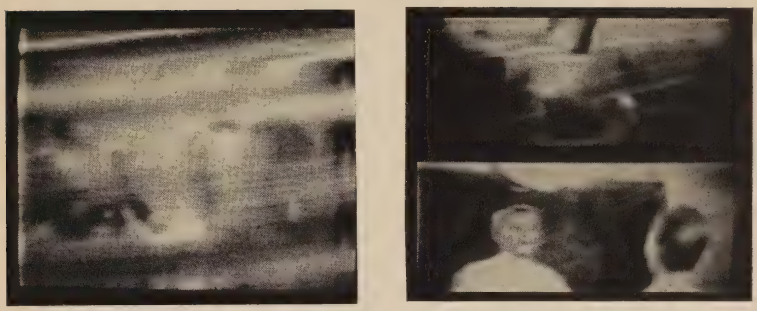

FIG. 53.—Characteristic appearance of pictures with (left) poor line synchronisation and (right) poor picture synchronisation.

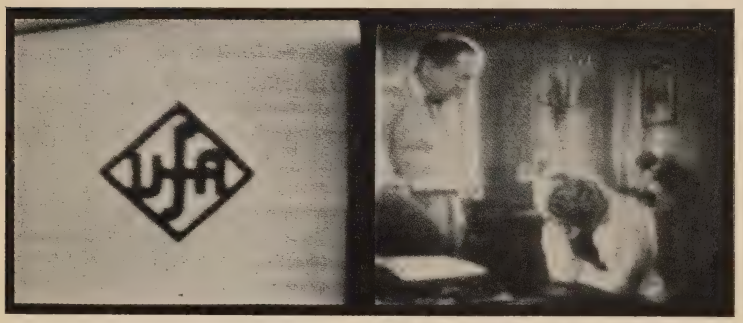

FIG. 54.—Incorrect (left) and correct phase (right) of the line synchronising impulse in a received picture. In each case the *amplitude* of the impulse is correct.

[*To face p.* 68.

PLATE XXII

FIG. 55.—Reduced picture definition due to uncontrollable wandering of successive lines brought about by interference created by too strong a synchronising impulse.

[*To face p.* 69.

line fly-back properly darkened and the hypothesis of contrasty and interference-free reproduction in the black parts justified.

It should be observed that the stability of the synchronisation is much reduced if the received frequency-amplitude curve is a poor one. In particular, the reduction of the synchronising signal (*i.e.*, the lower limit of signal amplitude) is often followed by severe plastic. Plastic is an effect which makes the image appear as though it were in bas-relief and is generally due to an absence of the lower and intermediate frequencies of the picture modulation band.

A synchronising signal which is too strong, especially at a great distance from the transmitter, and when the amplitude is not particularly well balanced, produces uncontrollable shifting of the lines with relation to one another. Interference from outside, or internal interference (for example, shot effect), produces a noticeable effect on the firing voltage of the thyratron, and hence on the line length, when the synchronising signal is too strong. The picture quality, particularly the amount of definition, suffers greatly, as shown by Fig. 55, when compared with Fig. 54 (left). The band width of the television receiver often limits the reception of light control voltage less than it limits the disturbance. Further, in the interest of obtaining the lowest possible interference level compared with signal level, a flat frequency curve must be obtained.

The time base voltage produced in the above-mentioned circuit appears at the grids of the amplifying valves V5 and V7. Even the bias voltages of the output stages are smoothed in a special manner in order to avoid the possibility of light modulation by changes in bias.

G. The Production of the Balanced Deflection Voltages

In order to obtain the balanced deflection voltages, the necessity for which is described in the chapter on television tubes, the output stage of the line time base is constructed in the form of a push-pull stage. In spite of the fact that a balanced output is not necessary, a push-pull output stage is used even in the picture portion of the time base. The push-pull arrangement is used here only to permit of the use of a higher inductance for the deflecting coils, which then give a correspondingly greater deflection without slowing down the fly-back velocity below the critical

value. For smaller picture formats it is quite sufficient to use only the amplifier and to omit the balancing valve. In this case, it is advisable to use a screen grid valve amplifier in order to obtain a small time constant. Only when the time base has a very low anode voltage supply is a push-pull arrangement for the picture portion essential with small picture formats. Balanced deflection is necessary if the deflection in the picture direction (low frequency) is also to be obtained electrostatically. In this case the resistances R29, R30 and R31 should be of the same value as R26, R27 and R28. Moreover, the coupling of the deflecting plates to the anodes of the push-pull valves of the picture portion of the time base must be accurately arranged, as shown in the line portion of Fig. 51. It must be mentioned in this connection, that the use of a transformer for the output of the picture portion of the time base is out of the question, because of the very low frequency components involved.

The series resistances in the discharge circuit of the valves (R18 and R19) are not employed only as protective resistances. They accelerate the fly-back of the time base in conjunction with the amplifying stage. This effect of the resistance in the discharge circuit appears at first sight to be somewhat unexpected, especially in view of the oscillogram (Fig. 46). It will be clear that the slowing effect in the discharge circuit will be more than outweighed by the accelerating effect which occurs, because at the instant of discharge a high potential appears across the resistance which substantially increases the potential at the grid of the output stage. For example, the line time base fly-back can be reduced to about a third of the normal time by the insertion of the resistance R18.

Since the time base is itself unbalanced, the use of transformers between the time base condenser and the amplifying stage is not permissible because of the load imposed upon the time base by a transformer, and therefore the input voltage for the balancing stage is not available without a further operation. This is done, in the circuit of Fig. 51, by taking a portion of the voltage from the anode of the main amplifier and feeding it to the grid of the balancing valve. The voltage is so adjusted that the same amplitude appears on the grid of the balancing stage as on the grid of the main amplifier. If this requirement is fulfilled the balanced output is obtained in a simple manner by

connecting the deflecting plates of the cathode ray tube between earth and the output terminal of the main amplifier and between earth and the balancing stage. In each case the same deflecting

Parts List for the Circuit of Fig. 51.

T1	Mains Transformer						
	Secondary	2	windings	each	1,400	volts,	60 ma.
	Rectifier	2	,,	,,	2	,,	3 amps.
	Heaters	2	,,	,,	2	,,	2 ,,
	,,	2	,,	,,	2	,,	2 ,,
	,,	2	,,	,,	2	,,	4 ,,
D1	Mains Choke					20	henries, 60 ma.
R1	50,000	ohms.				20	watts
R2	50,000	,,				20	,,
R3	500	,,				1	watt
R4	10,000	,,				1	,,
R5	10,000	,,				1	,,
R6	10,000	,,				1	,,
R7	500	,,				1	,,
R8	10,000	,,				1	,,
R9	10,000	,,				1	,,
R10	3,000	,,				2	watts
R11	100	,,				0·5	watt
R12	100	,,				0·5	,,
R13	2,000	,,				0·5	,,
R14	0·1	megohm.				2	watts
R15	7	megohms.				3	,,
R16	0·1	megohm.				2	,,
R17	7	megohms.				3	,,
R18	5,000	ohms.				1	watt
R19	1,000	,,				1	,,
R20	0·5	megohm.				0·5	,,
R21	0·5	,,				0·5	,,
R22	5	megohms.				1	,,
R23	0·05	megohm.				1	,,
R24	5	megohms.				1	,,
R25	0·25	megohm.				1	,,
R26	75,000	ohms.				15	watts
R27	25,000	,,				6	,,
R28	100,000	,,				15	,,
R29	30,000	,,				15	,,
R30	10,000	,,				6	,,
R31	40,000	,,				15	,,
R32	0·5	megohm.				2	,,
R33	0·5	,,				2	,,
R34	0·1	,,				3	,,

Parts List for the Circuit of Fig. 51—continued.

R35	4,000	ohms.	0·5 watt
R36	700	,,	1 ,,
R37	5,000	,,	1 ,,
R38	10,000	,,	1 ,,
R39	0·25	megohm.	1 ,,
R40	2·0	megohms.	1 ,,
R41	3,000	ohms.	0·5 ,,
R42	3,000	,,	0·5 ,,
R43	75,000	,,	15 watts
R44	7,500	,,	15 ,,
R45	1,500	,,	0·5 watt
V1	2 Leybold Rectifiers or, 2 SU2130 (Cossor)		
V2	MS/PEN	,,	
V3, V4	GDT 4	,,	
V5, V6, V7, V8	41 MP	,,	
C1	8	MF.	3,000 volts
C2	8	,,	3,000 ,,
C5	20	,,	50 ,,
C6	10,000	mmF.	
C7	15,000	,,	
C8	20	MF.	50 volts
C9	20	,,	50 ,,
C10	20	,,	50 ,,
C11	1,000	mmF.	
C12	300	,,	
C13	100	,,	
C14	0·1	MF.	2,000 volts
C15	0·2	,,	2,000 ,,
C16	0·4	,,	2,000 ,,
C17	0·1	,,	1,500 ,,
C18	0·2	,,	1,500 ,,
C19	0·1	,,	1,500 ,,
C20	2	,,	2,000 ,,
C21	0·01	,,	2,000 ,,
C22	0·01	,,	2,000 ,,
C24	20	,,	50 ,,
C25	4	,,	3,000 ,,
C26	1	,,	3,000 ,,

potential exists. The potential fed to the grid of the balancing valve does not depend only upon the anode resistance, as is usual with this type of push-pull stage, but also upon the values of the resistances R23 and R39 or R25 and R40 in the grid circuits. As a result there is the advantage that the ripple-

voltage of the D.C. supply system is reduced by the potentiometer action of the circuit, so that only a small part of the total hum reaches the grid. In this way substantially better smoothing of the supply ripple on the grid is obtained.

The time constant of the anode circuit in the line time base portion, which essentially fixes the fly-back time, must be made as small as possible by using an anode connecting lead having as small a stray capacity as possible. The wires to the deflecting plates must, above all, be as short and as free from capacity as possible. One must take care that the capacities C21 and C22 shall have a small capacity to earth. The more the capacity is reduced the greater the efficiency of the time base amplifier. If the line time base fly-back appears in practice to be slow, particularly with a large number of lines, the velocity may be increased by reducing the anode resistances of the valves V5 and V6. The fly-back is sufficiently fast if it is only visible at the extreme left-hand edge of the picture.

The circuit of Fig. 51 is correctly drawn for earthing the anode of the cathode ray tube. In order to use this apparatus with the superheterodyne receiver which is to be described, it is necessary to alter it to make it suitable for earthing the cathode of the cathode ray tube. To do this it is only necessary to arrange that part of the circuit which is joined to the deflecting plates, as shown in Fig. 52. Furthermore, the test voltage for the small condensers, C21 and C22, must be increased to between 10,000 and 15,000 volts, according to the anode voltage selected.

H. Serious Faults and their Correction

In order to reduce interference between the line and picture time bases as much as possible, the anode circuits of the amplifying stages must be additionally smoothed. This is also of value with the very high currents required for magnetic deflection. At the same time the smoothing resistances serve to reduce the anode potential for the amplifying stages, so that the valves V7 and V8 require, at the most, only 6 watts.

An adjustable D.C. potential is provided by means of the potentiometer R34, or by the use of the arrangement described for earthing the cathode (Fig. 52), so that the balance between the D.C. deflecting plate potentials is somewhat upset, in order to bring the picture raster to the centre of the screen. This arrange-

ment is useful, in order to compensate for the deflection which arises, due to the earth's magnetic field in the horizontal direction.

In order to avoid interference between the different portions of the time base, separate heater windings are provided for the individual valves, exactly as shown in Fig. 51. This remark also applies to the high-vacuum time base already described, a separate winding being necessary for the valve Vb in the circuit diagram (Fig. 48).

The values of the component parts of the circuit are so arranged that a very good characteristic exists and trouble-free operation is possible. The mains ripple is so much reduced that practically no interference is detectable.

The presence of a more or less intense ripple is one of the most frequent faults of time bases. This fault manifests itself in various ways, depending upon whether the ripple is in the line or the picture time base. If it is in the line time base the sides of the picture will be more or less wavy : according to whether the ripple affects the thyratron or only the amplifier, only one or both sides will appear wavy (see Fig. 43). Ripple in the picture time base exercises a peculiarly critical effect. A small residual interference will be almost sufficient to prevent the transmitted synchronising signal from effecting the picture change. Even if the synchronising effect due to mains ripple is smaller than that due to the synchronising signal, the ripple is still very disturbing, since it causes jumping of the picture with particular phase conditions. Special attention must therefore be given to the removal of D.C. supply ripple.

If the synchronisation appears to depend upon the line and picture time bases, *i.e.*, if, for example, the picture-frame can only be properly synchronised when the lines are not synchronised, the connection of a small condenser between the grid and cathode of the picture time base discharge tube is to be recommended. The amplitude of the high-frequency components of the line time base output appearing in the picture synchronising circuit will be sufficiently reduced with a condenser of about 1,000 mmF.

The picture deflecting current is taken from the anodes of the push-pull stage. A large and expensive condenser must be inserted if the push-pull output stage is not well balanced, because, in this case, a D.C. current will flow in the deflecting coil circuit. If the condenser is omitted, part of the resistance

FIG. 56.—Front view of the push-pull double time base with incorporated amplitude filter.

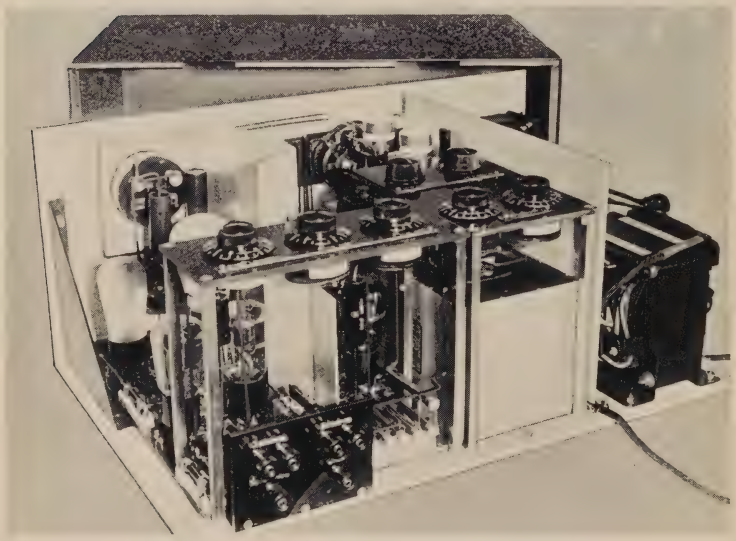

FIG. 57.—Rear view of the push-pull time base.

[*To face p.* 75.

R31 should be made adjustable, so that the D.C. component of the anode voltage may be brought to a balance. This resistance may also be used to adjust the position of the raster on the screen in the picture direction. However, raster position is still better adjusted by varying the bias on one of the two amplifying valves of the push-pull output stage. The deflecting coils, whose form and arrangement have already been shown in Fig. 19, may have some 5,000 to 6,000 turns, when connected in push-pull, without critically reducing the velocity of the fly-back. These numbers are reduced to 3,000 or 4,000 turns if an iron-core coil is used. It should be noted that these statements refer to coils having an inner dimension of $5 \times 3\frac{1}{2}$ cm.

J. Construction and Operation of the Push-Pull Time Base

Fig. 56 shows the apparatus constructed in accordance with the circuit of Fig. 51. The mains switch can be seen on the left-hand side of the panel, and in the centre (above and below) six potentiometers are arranged. These require to be operated when the apparatus is first put into service and when television pictures are received. On the right are the bias control and the meter in the anode circuit of the amplitude filter which will be described in the following section. A rear view of the same apparatus is shown in Fig. 57. On the right the mains rectifying apparatus can be seen, separated from the remainder by a screen. A screen is also provided between the picture and line time bases. A view of the same apparatus, from above, is given in Fig. 58. The knobs of this apparatus, which are seen in Fig. 58, are for the adjustment of the grid bias for the amplifier stages and for the fine adjustment of the input voltage for the balancing stage. Finally, the control for the centre tap of the line time base output is visible on the extreme right. In this apparatus, which is designed for experimental work, all the resistances are easily changeable. Of course, for practical purposes, it is advisable to employ components which are used for broadcast reception and which are cheaper in consequence.

The operation of the apparatus takes place in the following way :

After connecting the deflecting plates of the cathode ray tube to the line time base terminals and the deflecting coil unit to the picture time base terminals, the apparatus is ready for operation. It takes about two minutes for the apparatus to heat. One must

then take care to adjust the coils so that a rectangle appears on the screen. Furthermore, the time base amplitudes should be adjusted, by variation of the thyratron bias, to provide such an output that the ratio of the lengths of the sides of the rectangle corresponds to the transmitter format, and also that the fluorescent screen is covered right up to the edge. The distorting effect of an incorrect format on the picture is shown in Fig. 59. Next, the line and picture frequencies are adjusted approximately to the correct values. Finally, one must see that the high-frequency voltage is fed to the input of the amplitude filter to obtain synchronisation.

The synchronising voltage potentiometers are, if necessary, re-adjusted after further adjustment of the time base frequency controls so that accurate synchronisation is maintained for long periods of time.

Where there is no practical experience of the appearance of the picture raster with incorrectly adjusted time base frequencies, it is easily possible to adjust the apparatus so that it is synchronised with any whole-number ratio of the correct frequency. In this case a form of distortion, which is peculiar to this fault, will appear on the fluorescent screen. Fig. 60 shows a received picture in which the picture frequency is correct, but in which the line frequency has only half its proper value. By keeping the correct picture frequency but with the picture amplitude reduced to a half, one obtains two undistorted pictures side by side. Fig. 61 shows a photograph of a fluorescent screen taken in these conditions. With this arrangement one is reminded of the well-known stereoscopic pictures. Indeed, in this way, it is very easy to obtain reception of television images in relief. For this purpose it is only necessary for the transmitter to send two images viewed from two slightly different positions and to scan alternate lines from alternate view points. The received picture, Fig. 61, will then be seen in stereoscopic relief. By the division into two pictures one gains the advantage that only half the normal number of lines is used for each picture and therefore the frequency band is not increased. The definition in the picture direction need only be half as great as with normal conditions. On the other hand, the definition in the line direction is unchanged. In order to make stereoscopic television yield the same definition for individual images as is obtained with normal television, double the frequency band is necessary. Obviously one can obtain more

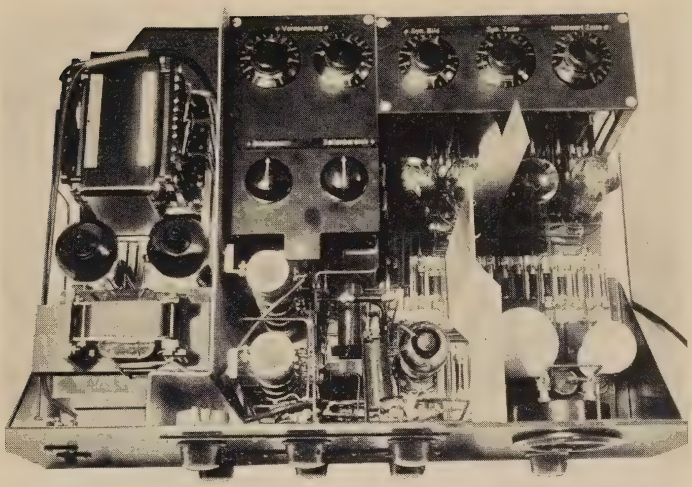

FIG. 58.—The double push-pull time base as seen from above.

FIG. 59.—The effect of incorrect adjustment of the picture format (5 by 6·7 instead of 5 by 6—Scene from " Congress Dances.")

FIG. 60.—Appearance of a picture with incorrect line-frequency adjustment (half correct value.)

[*To face p.* 76.

PLATE XXV

FIG. 61.—The effect of using half the correct line-frequency and half picture amplitude. (The cross definition is halved, but the definition along the lines is as usual.)

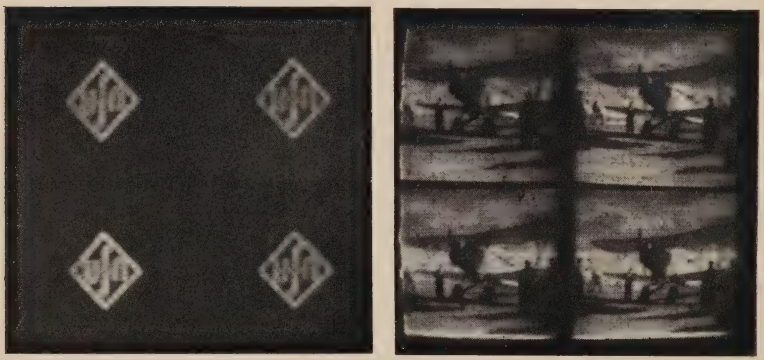

FIG. 62.—Four adjacent pictures obtained as a result of adjusting the line and picture frequencies to a half of their correct values.

[*To face p.* 77.

than two pictures on the screen with other line and picture frequencies. Fig. 62 is a photograph of four pictures taken from the end of a cathode ray tube during a film transmission from the Berlin station. Colour television is fundamentally possible by the use of suitable time base frequencies. Three pictures, in the three primary colours, are produced in proximity to one another at the receiver, and care is taken to make the images coincide exactly by optical means. Screen materials with maximum radiation in the three colours are already known, and have been described in Chapter III. The transmitter must operate with the same colour order as at the receiver for the three pictures, each of three successive lines being scanned with one of the three primary colours in the correct sequence. The frequency band for colour television is three times as large as for normal picture transmission, if the same definition is used in individual images.

The above-mentioned possibility of receiving multiple pictures is also of interest in so far as in this way the possibility of reproducing pictures with a very much smaller number of lines can be demonstrated by comparison.

When the apparatus is first put into service, it is advisable to test the various parts to ensure that they function correctly, on account of the large number of possible faults. One should find out by making measurements whether the potentials are of approximately the correct value. Further, by visual observation of the picture time base thyratron one can see whether the latter is operating correctly or not. By checking the amplifier characteristics with the cathode ray tube, one can establish that the grid-bias voltages for the amplifying stages are of the correct value. The existence of mutual interference between the two time bases is checked most simply by means of a pair of headphones, of which only one lead is connected. One should observe whether the picture and line frequencies are heard separately, or whether the line time base frequency is noticeable in the picture time base output, or *vice versâ*. Coupling between the time bases is detectable in the picture by poor synchronisation and by a side displacement of the lines at the beginning of the picture.

When the transmitter and receiver are operated from the same supply mains, the picture synchronisation can be taken from the mains. For this purpose a potential of a few volts in the correct

phase may be taken from the mains to the synchronising potentiometer R38, in Fig. 51. Within certain limits, phase variations, due to very slow changes in load on the mains, can be rectified by adjustment of the picture frequency control. The apparatus, in accordance with Fig. 51 and with the values shown in the parts list, is able to deliver time base output voltages up to a maximum of 2,000 volts and, in conjunction with the deflecting coils already described, to produce sufficiently large magnetic deflecting fields to provide a normal format. A linear characteristic is obtainable from each time base. Stable synchronisation and freedom from interference is obtained by the extraordinarily good smoothing and de-coupling which has been provided. With a compact form of construction of the time bases and with the cathode ray tube in close proximity thereto, it is necessary to ensure that no transformer stray field can affect the raster.

Stable synchronisation, which is independent of the transmitted picture content, is only obtainable if the amplitude filter, described in the following chapter, is provided.

CHAPTER V

THE AMPLITUDE FILTER FOR SEPARATION OF THE SYNCHRONISING IMPULSES

The synchronisation of the time base will be very much dependent upon the picture content, and will consequently be unstable if the output voltage from the final stage of the intermediate-frequency amplifier is fed directly to the two gas discharge valves *viâ* the synchronising potentiometers. Similarly, poor synchronisation occurs if the high frequency is rectified in the usual way, and the resulting synchronising impulses are fed to

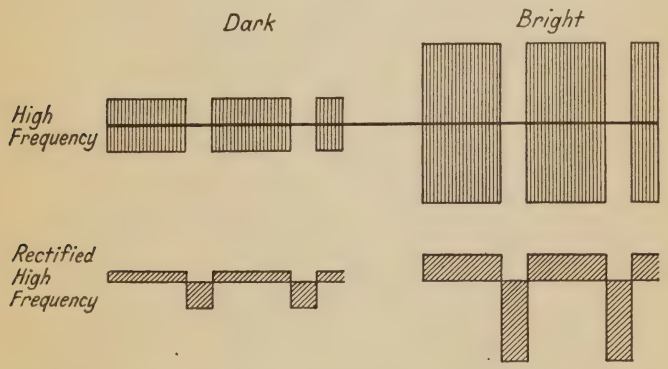

Fig. 63.—The dependence of the synchronising signal amplitude on the mean picture and line brilliancy value.

the thyratron grids. In the first chapter, the oscillograms Figs. 4 and 5 show the wave-form of the high-frequency oscillations with two different conditions of transmitter output. In the upper portion of Fig. 63 is shown (schematically) the high-frequency signal shape for the two limiting cases in which the transmitter sends a black or a white signal. The lower portion of Fig. 63 shows the shape of the pulse obtained after rectification, and with the D.C. component removed, in each of the above limiting conditions. From this, one can see that, with the method described,

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the height of the synchronising impulse depends on the mean picture or line brightness value. When the mean brightness is great the amplitude of the synchronising impulse is also great and *vice versâ*. As the size of the synchronising impulse has considerable effect on the operating value of the thyratron, displacement of the lines, changes of line length and variations in picture synchronism will occur, and will depend upon the mean picture brightness. In order to obtain satisfactory synchronising impulses with the method of control at present in use, in which the amplitude is independent of the mean brightness value, it will be necessary to arrange for rectification by means of a so-called amplitude filter.

A. The Method of Operation of the Amplitude Filter

Amplitude filters are known in connection with printing telegraph receivers on short waves. Fig. 64 shows the method of

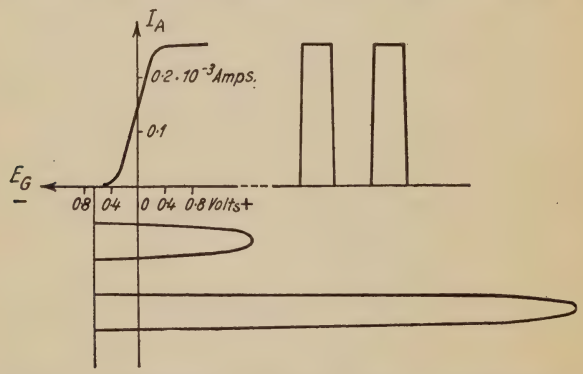

Fig. 64.—The method of operation of an amplitude filter.

operation which is on the same fundamental basis as is required for television reception. For faultless operation of the filter, to a first approximation, the presence of a characteristic with precise upper and lower bends is required. Furthermore, the characteristic must be " swept over " by a potential which is small compared with the high-frequency output of the intermediate-frequency amplifier. If the effective value of the intermediate-frequency voltage when the transmitter is modulated to the dark condition amounts, for instance, to 3 volts, then the characteristic curve of the amplitude filter must have a slope such that changes of about 1 volt are sufficient for complete control. In this case,

if the characteristic curve does not continue to rise after the upper bend, the increase of the mean value of the current in the anode circuit of the amplitude filter, for increasing grid potential, remains relatively small, as already shown in Fig. 64. With the aid of this arrangement, an almost constant synchronising impulse amplitude is obtained with varying picture content. With the amplitude filter to be described, no changes in line position with large changes in brilliancy are observed, and the picture synchronisation is independent of the picture content. The sensitive milliammeter in the anode circuit of the amplitude filter enables one to make sure that the filter is working correctly. The pointer of this instrument must be damped so that it does not swing if the transmitter sends pictures of alternate black and white squares, or if the input voltage is varied within the same limits, for example, by varying the pre-selector circuit of the radio receiver.

The grid bias in Fig. 64 is made more negative than the value which is most suitable for the filter. This is done in order to keep interference out of the synchronising circuits with weak field strengths, since this would otherwise lead to variations in line position (see Fig. 55). Only with such a choice of bias will the synchronising impulses have a constant amplitude at great distances from the transmitter.

For correct operation, as already mentioned above, the existence of a characteristic with sharp upper and lower bends, together with the unusually small grid base of about 1 volt, is necessary.

One can only obtain a sharp upper bend with modern oxide-cathode triodes when relatively high anode resistances are used. The upper bend resulting therefrom will be such that the anode current is always smaller than the value obtained by Ohm's law from the values of the anode potential and the anode resistance. In order to permit the upper bend to operate with the smallest possible positive instantaneous grid voltage, a high anode resistance and low anode potential are used. In this way, the important upper bend remains even in the dynamic condition, and the sharpness of the bend, as measured in the static condition, is also kept, but only if the anode resistance is of sufficiently low value that stray capacities may be neglected. In order to reduce these capacities, the anode resistance of the amplitude filter may be divided into sections. With a high control sensitivity of the thyratron a small portion of the anode A.C. potential is often

sufficient to provide stable synchronisation. The shape of the characteristic of a triode used in the above manner is shown in Fig. 65. Since the valve is, in part, operated in a positive grid condition, one must take this fact into account if valves having a large amount of grid current are employed. In order to obtain satisfactory operating conditions, the characteristic must be plotted with all grid leaks in circuit. It is known that the charac-

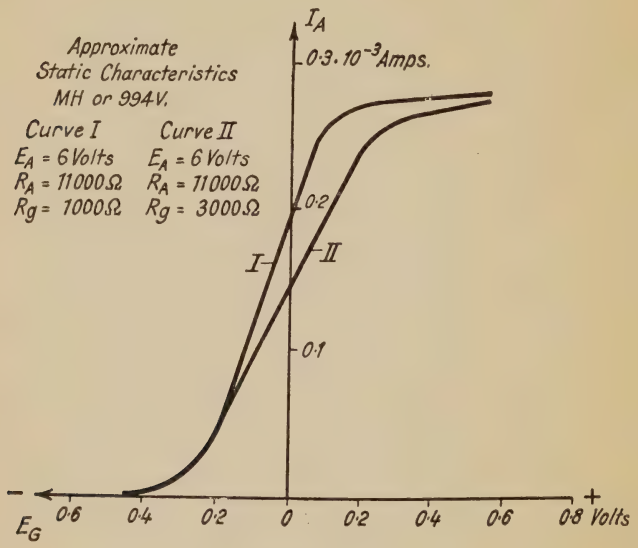

FIG. 65.—The characteristics of a triode limiter valve.

teristic is rather less steep from the point where grid current commences, when high values of grid leak are used. In spite of this fact, it is advisable to use a large value of grid leak, since the proportion of signal voltage on the grid of the filter, for an increasing value of grid leak, at first increases more rapidly than does the bias control range of the characteristic.

B. An Amplitude Filter using a Screen-grid Valve

The arrangement using a triode with the increased value of grid leak resistance possesses an upper bend which is not very sharp, as is shown in Fig. 65 ; moreover, even beyond the bend, the characteristic rises slightly. An amplitude filter using a

screen-grid valve as shown in Fig. 51 operates in a more satisfactory manner. In this way the entire curve, including the upper bend, can be displaced towards the negative end of the grid base due to the presence of the positive screen-grid, so that one can, in principle, operate even with the larger values of grid leak. On account of this fact, and as a consequence of the steep slope of the characteristic, the power absorbed by the filter can be reduced so that its load can be neglected compared with that of

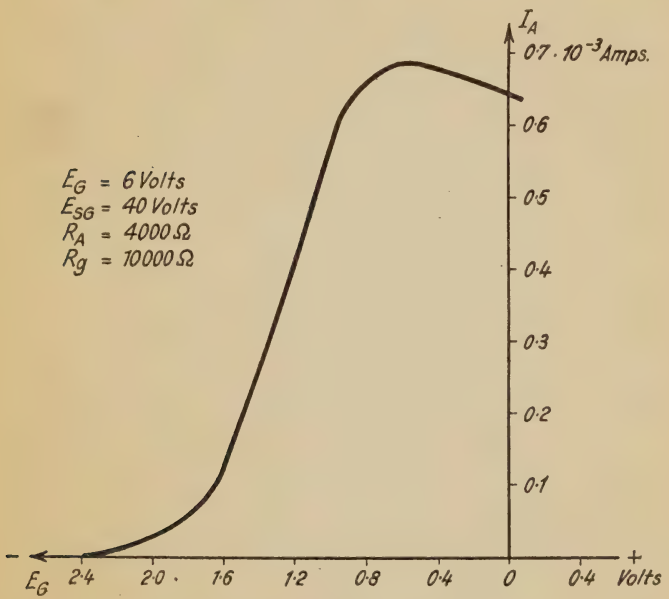

FIG. 66.—The characteristics of a normal screen-grid valve used as an amplitude filter.

the rectifier transformer in the final amplifying stage of the radio receiver. Very small capacities are sufficient to couple the grid of the filter to the output terminals of the radio receiver. Fig. 66 shows the characteristic of a filter with specified values. The anode and screen voltages are purposely chosen so that above the bend the current falls again due to the screen robbing the anode of current. This fall in the characteristic (above the bend) makes possible a compensation of the small increase of the mean value of the current with the amplitude of the signal.

By correct adjustment of the small rotary coupling condenser, *i.e.*, with the correct voltage at the grid of the filter, one can arrange that the filter anode current is completely independent of the amount of transmitter modulation lying within the brilliancy control portion. This complete independence ensures stable synchronisation of the picture and line time base voltages over long periods of time.

Synchronising difficulties, in particular dependence of the synchronisation upon the picture content, are nearly always due to poor operation of the filter, so that it is advisable to give full attention to this part of the equipment, to take characteristics and to make dynamic measurements to ensure faultless operation. This is of particular importance when using distant control (not self-running) time bases, since it is much more important in this case to have precise synchronising impulses than is the case with self-running time bases.

C. Other Methods of Filtering Out the Synchronising Impulses

The other method of separating the synchronising impulses is by means of highly selective circuits. Practical tests show that filtering out the synchronising frequency only is not so advantageous as is the use of an amplitude filter. But it is possible to increase the stability of the synchronisation by inserting a selective filter arrangement behind the amplitude filter. For instance, one can use circuits which are tuned to the line and picture frequencies and which are loosely coupled to the amplitude filter by resistances of about 10^4 ohms. The tuned circuits then replace the synchronising potentiometers and the control grids of the thyratrons are tapped down the coils.

Two different condenser-resistance circuits, which separate the different frequency line and picture impulses from one another, are inserted between the filter and the time base valves (Fig. 51). The circuit is so arranged that the grid current of the picture thyratron does not affect the steady bias value of the line thyratron.

It is quite obvious from the good results obtained that the synchronising impulses are properly separated by the method described. However, further research has been under consideration for some time for which one might modulate a sound transmitter or standard signal generator with line and picture synchronising signals. In this case, the sound amplifier must be so

adjusted that the audible range is well amplified, and one must arrange for separation of the synchronising impulse by means of a tuned circuit and rectifier.

It is, at the moment, impossible to determine whether distant controlled or self-running time bases will finally be adopted as standard practice. This is an interesting problem to which the television amateur can devote his attention, viz., to try to settle the question of synchronisation in television.

The amplitude filters described in this chapter are fed from the output of the intermediate-frequency amplifier, while that which forms part of the hard valve time base shown in Fig. 48 is fed from the output of the second detector of the vision receiver.

CHAPTER VI

THE DETECTOR

While the separation of the synchronising impulse from the picture modulation requires a valve specially adapted for the purpose, as explained in the last chapter, the separation of the brilliancy control potential is obtained in a more simple manner. As a rule it is sufficient to adjust the bias of the grid of the cathode ray tube to the correct value (see Fig. 37).

Since, with the present transmitter arrangements, the D.C. component of the picture is to be transmitted, the receiver is capable of reproducing pictures with the correct mean level of illumination. To this end, it is only necessary to ensure that a direct connection shall exist between the detector and the grid of the cathode ray tube. It is only possible to obtain correct reproduction of pictures having light and dark scenes if the D.C. component is passed on to the modulating grid of the cathode ray tube. Since the quality of the picture depends to a large extent upon the utilisation of the D.C. component, the author has limited the book to descriptions of apparatus which fulfil this requirement.

A. Rectification in the Cathode Ray Tube and its Disadvantages

The simplest method of coupling the second detector and the modulating grid directly to one another is to arrange for detection to occur inside the cathode ray tube. To do this it is only necessary to connect the intermediate-frequency output directly to the grid of the cathode ray tube by means of a condenser. In order to permit of a D.C. potential drop between the grid and the bias terminal of the mains power unit, a resistance of some 20,000 ohms is inserted. This type of rectifier is sufficiently good for modest purposes; the cathode ray tube, however, becomes biassed back, so that the pictures are dark. For a proof of this assertion see Fig. 67. The characteristic of the cathode ray tube, which is similar to that of an amplifying valve, can only be

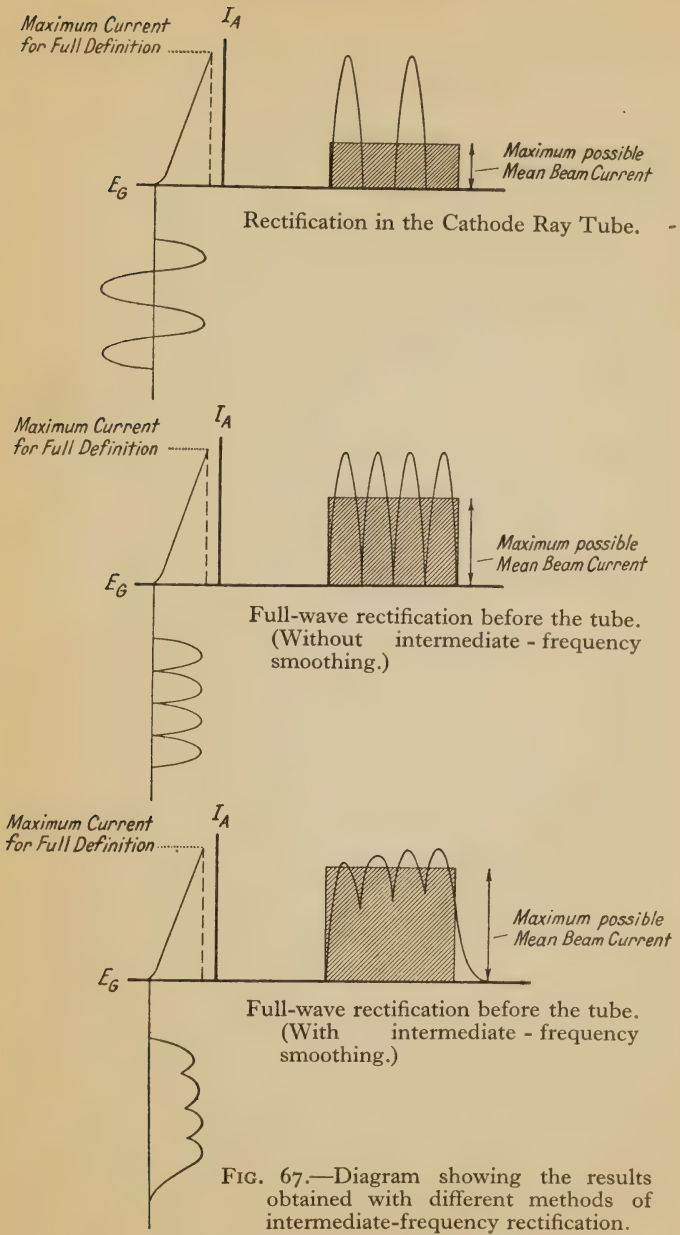
Maximum Current for Full Definition
I_A
E_G
Maximum possible Mean Beam Current
Rectification in the Cathode Ray Tube.
Maximum Current for Full Definition
I_A
E_G
Maximum possible Mean Beam Current
Full-wave rectification before the tube. (Without intermediate - frequency smoothing.)
Maximum Current for Full Definition
I_A
E_G
Maximum possible Mean Beam Current
Full-wave rectification before the tube. (With intermediate - frequency smoothing.)

FIG. 67.—Diagram showing the results obtained with different methods of intermediate-frequency rectification.

used up to a certain value of anode current. This value, which differs with different types of tube, fixes the limit of anode current above which the spot sharpness is insufficient for reproducing pictures with a given number of lines. One makes the fullest use of the tube if this maximum value of current is always obtained in the brightest parts of the picture. As is shown in Fig. 67, this is by no means the case when rectification takes place inside the cathode ray tube. Only for short periods of time, when the intermediate or high frequency is at the peak value, is the maximum value of anode current obtained, while for the remainder of the time a very much smaller anode current flows and no current at all during the other half wave. The mean value of anode current is thus only about a third of the maximum value. The pictures are also only about a third as bright as they might be if the full value of anode current of the cathode ray tube could be used.

B. A Full-wave Rectifier Circuit for the Second Detector and its Advantages

Substantially better results are obtained if the rectifier is arranged, not as a single-wave rectifier inside the cathode ray tube, but as a separate rectifier placed in circuit before the tube. With full-wave rectification the pictures are of twice the brilliancy as, in this case, the mean value of the anode current reaches nearly two-thirds of the maximum value, as is shown in the centre of Fig. 67. Still better results are obtained if parallel capacities are used to smooth out variations so that the control voltage does not reach such high values at the instant when the high frequency is at its peak value nor, on the other hand, does it fall to dark at the zero point. A limit to the amount of smoothing by capacity across the rectifier output is introduced by the resultant lack of definition in the picture due to the discharging time of the condenser being too great. It is recommended that care be taken in the use of this method. However, 75 to 80 per cent. of the cathode ray tube characteristic can be utilised when intermediate-frequency full-wave rectification is used in front of the cathode ray tube and when the intermediate-frequency output is by-passed. A full-wave rectifier circuit which by-passes the intermediate-frequency output and which has proved to be of value during the author's researches is shown in Fig. 68. The

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bias terminal shown in Fig. 68 is connected to the corresponding terminal of the mains unit and the control grid terminal is connected directly to the grid of the cathode ray tube. Since this part of the circuit is at high potential to earth when the anode of the cathode ray tube is earthed, the rectifier must, in this case, be arranged so that all parts are sufficiently insulated from earth. This is the case with the components mentioned. The high-voltage condenser in Fig. 68, which is provided for 50-cycle smoothing, can, however, be replaced by one of 300 mmF. if the

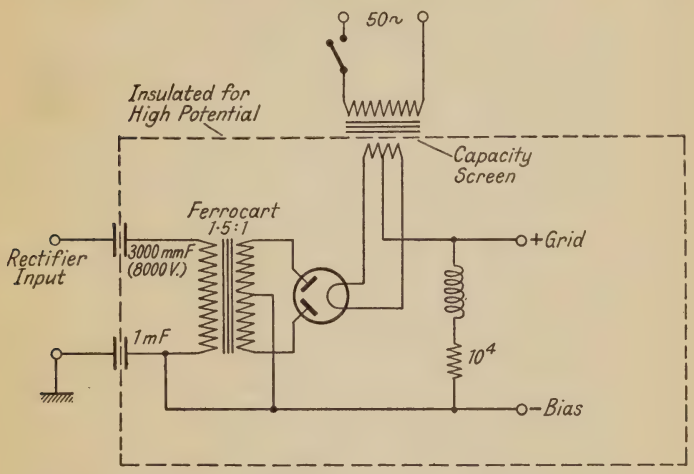

Fig. 68.—The circuit of a full-wave intermediate-frequency rectifier.

mains rectifier circuit of Fig. 39A is used. The arrangement of the circuit for use with a cathode ray tube whose cathode is earthed is given below (see Fig. 70), in which the circuit of the picture superheterodyne receiver is shown together with the intermediate-frequency rectifier.

The intermediate frequency, which, in the receiver to be described in the following chapter, covers a band of about 0·5 to 2 million cycles per second, is fed *viâ* a Ferrocart transformer to a double diode. This valve is heated by means of a low-capacity winding (insulated for the appropriate high potential) on the mains transformer.

Particular attention must be given to the connection of the

Ferrocart transformer to the final amplifying stage, since this can seriously affect the resultant frequency-amplitude characteristic. The connections must be so arranged that it has just the correct damping to provide the required characteristic. It is recommended in cases where excessive damping proves necessary, that " useful " damping be employed, *i.e.*, that a valve having a low internal impedance be used for the final intermediate-frequency amplifying stage.

The stray capacity of the circuit should itself be utilised for levelling the intermediate-frequency characteristic. The resistance shown in Fig. 68 ensures a sufficiently short time constant. A suitable value for this resistance is 5,000 to 10,000 ohms, a value which will provide good picture definition with full use of the ray tube characteristic and with large brilliancy control-potentials. The choke shown, which increases the dependence of the smoothing section upon the frequency, within the range of the intermediate carrier frequency and the highest modulation frequency, is not absolutely necessary. Fig. 69 shows the construction of an intermediate-frequency rectifier made in accordance with the circuit shown in Fig. 68. In the middle, on the left, is the screened Ferrocart transformer, and the double diode can be seen in the centre ; on the right are the resistance and the high-frequency choke. When the anode is earthed, these parts are all at high potential and, therefore, the parts and their connecting leads should be at least a few centimetres from the box.

The intermediate frequency is still visible in the raster when the full-wave rectifier is in use. On account of the high definition of the cathode ray tube, one gains the impression that the lines are split up into adjacent spots and in this way the raster obtains the appearance of a printer's screen.

Experience has shown that it is not easy to make the full-wave rectifier operate in a faultless manner. Serious unbalance to earth of the transformer winding capacity shows up at high frequencies. This asymmetry is easily seen in the raster, since alternate black and white intermediate-frequency spotting appears. In particularly bad cases, the lack of symmetry is so great that the second half wave is unused. The amount of unbalance may be determined by measuring the voltage across the two halves of the winding on the secondary of the transformer with a cathode ray

PLATE XXVI

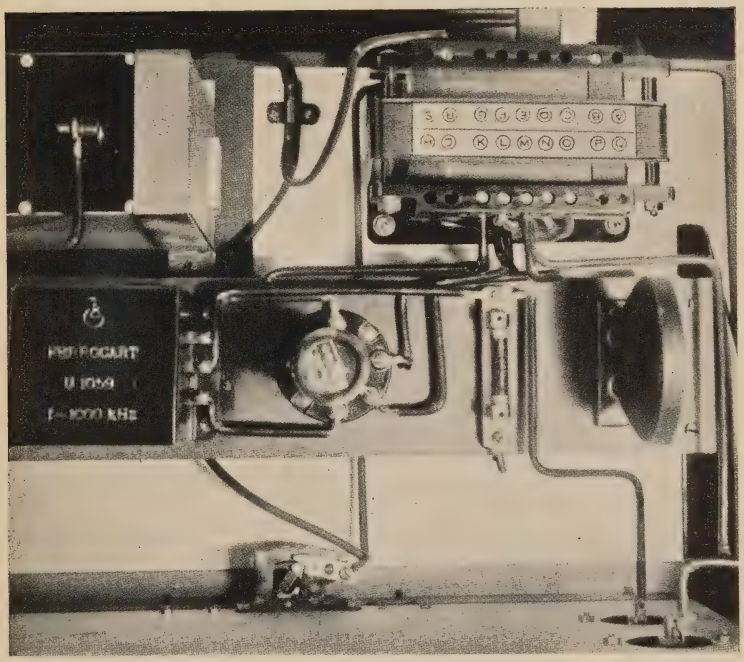

FIG. 69.—The construction of the intermediate-frequency amplifier with double-diode detector.

[*To face p.* 90.

tube or by means of a switching test. The degree of unbalance with various values of intermediate frequency can also be obtained in this way. Symmetry depends to a great extent upon the output of the final amplifying stage. Good symmetry can only be expected when the working point for the carrier frequency lies in the centre of the straight portion of the characteristic, and if one is satisfied with a moderate output. If one wishes to avoid the difficulties of balancing the full-wave rectifier, it becomes necessary to increase the intermediate frequency considerably. With intermediate frequencies of about 6 megacycles one obtains equally good use of the cathode ray tube, even with a single-wave rectifier, as is shown (for full-wave rectification) in Fig. 67.

The output stage of the intermediate-frequency amplifier described in the following chapter requires to have more or less amplification depending upon the potential required to modulate the cathode ray tube from light to dark.

CHAPTER VII

THE ULTRA-SHORT WAVE PICTURE SUPER-HETERODYNE RECEIVER

The superheterodyne picture receiver has the important task of delivering two potentials under the control of the television transmitter :

(1.) The light control voltage which appears at the grid of the cathode ray tube and which determines the picture structure and the mean brilliancy.

(2.) A voltage which is fed to the grid of the amplifier filter to provide synchronising impulses of constant amplitude for the control of the time bases.

In order to obtain perfect reproduction of the pictures, the intermediate-frequency amplifier must have a band width of about 2 Mc. for receiving the Baird transmission, or 4 Mc. for the EMI pictures if both side bands are utilised. To fulfil this requirement is extremely difficult, as is shown by publications devoted to work on aperiodic high-frequency amplifiers. A very high intermediate frequency may be used (for instance, 6 to 10 Mc. per second) and band filters may be employed as coupling sections. The correct matching of intermediate-frequency stages with their band filters is, however, very difficult and is hardly possible without short wave measuring equipment. With the apparatus described below, a much lower intermediate frequency is used together with choke-resistance combinations, for which special matching is unnecessary for interstage coupling.

The use of only one side band in the intermediate-frequency amplifier in order to halve the necessary transmission band is permissible in this case. If only one side band is used the carrier frequency must be adjusted by suitable choice of oscillator frequency, so that it lies in the neighbourhood of one end of the transmission band of the intermediate-frequency amplifier.

Since the transmission characteristic steadily rises due to damping and, on the other hand, since low modulation frequencies lie next to the carrier, both side bands are demodulated at the low frequencies, *i.e.*, twice the normal amplitude of light-control potential appears.

With the circuit having the values given below, it is easy to compensate for the resulting frequency characteristic. With the use of only one side band, in spite of the use of valves of the types usually obtainable which have hardly sufficient slope for television amplification, a receiving apparatus has been developed whose frequency characteristic permits one to work with modulation frequencies up to about 1·5 megacycles per second.

A. The Circuit of the Picture Receiver

The circuit of an ultra-short wave superheterodyne receiver having a sufficiently wide band is given in Fig. 70. By means of a heterodyne oscillator, an intermediate carrier frequency of about 1·2 to 2 Mc. is introduced, depending upon the frequency band of the received transmitter. As is seen from the circuit, the intermediate-frequency stages are of a more or less similar type. This is so arranged in order to produce the conditions upon which the necessary calculations are based. The calculations are simplified by using stages all of the same type, and indeed, without this condition, the calculations would have become extremely difficult. In the construction of the apparatus it is necessary to ensure that the smallest possible stray capacity is obtained and, in particular, there should be no extra capacity added between the anodes and grids of the valves. The screened-grid valves used here are noted for their low grid-anode capacity and steep slope. With the values given, the amplification of each stage is about 12 to 16 times, depending upon the slope of the valves used.

The frequency characteristic of the apparatus shown in Fig. 70, together with the rectifier, is of the following type :—

Towards the higher frequencies there is a steep fall which lies between 1 and 2 megacycles per second, depending upon the mean value of the stray capacities and upon the value of the anode resistances. The carrier frequency is so adjusted that approximately the degree of amplification mentioned above is obtained for the lower frequencies. In this region, where both

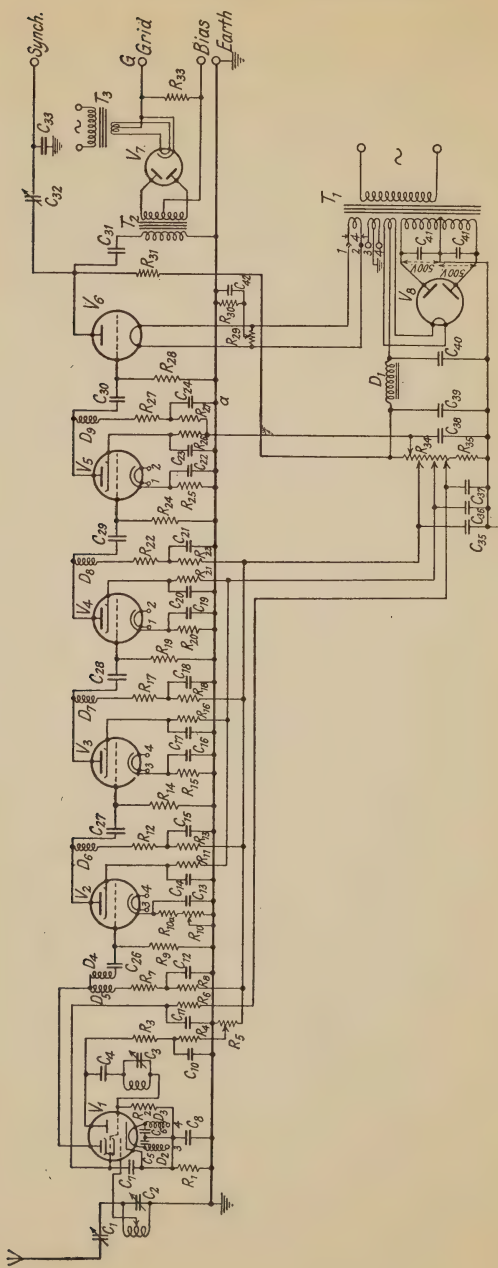

FIG. 70.—Circuit of the vision receiver.

side bands are demodulated, the amplitude appearing at the input to the intermediate-frequency circuit is doubled. This abnormal input will, however, be levelled out in the circuit, since

Parts List for the Circuit of Fig. 70

R1	300	ohms.	0·5 watt
R2	0·03	megohm.	1 ,,
R3	0·1	,,	2 watts
R4	2,000	ohms.	0·5 watt
R5	50,000	,,	3 watts
R6	2,000	,,	0·5 watt
R7	3,000	,,	0·5 ,,
R8	2,000	,,	0·5 ,,
R9	1	megohm.	0·5 ,,
R10	10,000	ohms. (log)	3 watts
R11	2,000	,,	0·5 watt
R12	3,000	,,	0·5 ,,
R13	2,000	,,	0·5 ,,
R14	3,000	,,	0·5 ,,
R15	300	,,	0·5 ,,
R16	2,000	,,	0·5 ,,
R17	100	,,	0·5 ,,
R18	2,000	,,	0·5 ,,
R19	1	megohm.	0·5 ,,
R20	300	ohms.	0·5 ,,
R21	2,000	,,	0·5 ,,
R22	2,000	,,	0·5 ,,
R23	2,000	,,	0·5 ,,
R24	1	megohm.	0·5 ,,
R25	600	ohms.	1 ,,
R26	0·1	megohm.	6 watts
R27	2,500	ohms.	3 ,,
R27a	2,500	,,	6 ,,
R28	0·1	megohm.	0·5 watt
R29	50	ohms.	1 ,,
R30	1 000	,,	3 watts
R31	2,500	,,	6 ,,
R33	7,000	,,	1 watt
R34	50,000	,, (2 of 20,000 ohms., each 6 watts 1 of 10,000 ohms., 3 watts)	
R35	25,000	ohms.	6 watts

T1 Mains Transformer

Secondary 2 windings, each 500 volts 125 ma.

Heater	2	,,	2	,,	4 amps.
,,	2	,,	2	,,	4 ,,
Rectifier	2	,,	2	,,	2 ,,

Parts List for the Circuit of Fig. 70—continued.

D1	Mains Choke	20 henries, 100 ma.
D2, D3, D4	Short Wave Choke (40 turns of 1 mm. wire on a diameter of 15 mm.)	
D5, D6, D7, D8	High-frequency Choke	0·3 mH., 1,500 ohms.
C1	15 mmF.	
C2	Short Wave Condenser	40 mmF.
C3	„ „ „	40 „
C4	100 mmF.	1,500 volts
C5	100 „	1,500 „
C6	100 „	1,500 „
C7	1,000 „	1,500 „
C8	5,000 „	
C10–C12	1 MF.	1,500 „
C13	0·1 „	1,500 „
C14–C15	1 „	1,500 „
C16	0·1 „	1,500 „
C17	1 „	1,500 „
C18	1 „	1,500 „
C19	0·1 „	1,500 „
C20	1 „	1,500 „
C21	1 „	1,500 „
C22	0·1 „	1,500 „
C23	1 „	1,500 „
C24	1 „	1,500 „
C26	500 mmF.	1,500 „
C27	500 „	1,500 „
C28	500 „	1,500 „
C29	500 „	1,500 „
C30	1,000 „	1,500 „
C31	1,000 „	1,500 „
C32	100 „	Rotary Condenser
C33	0·0001 MF.	2,000 volts
C35	6 MF.	1,500 „
C36	6 „	1,500 „
C37	6 „	1,000 „
C38	4 „	1,000 „
C39	8 „	2,000 „
C40	8 „	2,000 „
C41	2 × 0·1 „	3,000 „
C42	20 „	50 „
V1	X41 (Osram) or MPG (Cossor) with separate oscillator	
V2	MVS/PEN (Cossor)	
V3	MS/PEN „	
V4	MS/PEN „	
V5	MP/PEN or PT 41 (Cossor)	

Parts List for the Circuit of Fig. 70—continued.

V6	. . .	4XP (Cossor).
V7	. . .	DD4 ,,
V8	. . .	460 BU (Cossor) or DW 4 (Mullard)

for the corresponding frequencies, the intermediate-frequency amplification is halved. The result is a very smooth frequency characteristic which slopes somewhat towards the higher frequencies. The shape of the frequency characteristic corresponds almost exactly to the natural curve of an amplifier having choke-resistance coupling and the greater efficiency of this method is obvious. It is a disadvantage that it is necessary to adjust the oscillator frequency with great accuracy. However, the oscillator can easily be adjusted if the coils are made mechanically stable and reasonably independent of temperature and if a simple indicator, such as a wavemeter, is used for determining the intermediate carrier frequency.

For example, one may use as an indicator a circuit which is tuned to the required intermediate carrier-frequency and loosely coupled to the intermediate-frequency amplifier. This circuit is then temporarily connected to the grid circuit of the sound receiver.

The circuit of Fig. 70 can also be used for double side band reception if certain alterations are made. In this case, the chokes and anode resistances must be of somewhat smaller values. At the same time, valves having a steeper slope must be used so as to leave the gain per stage unaltered.

There are other more or less successful methods of constructing the intermediate-frequency stages. If the chokes are removed from the anode circuit, it becomes necessary to reduce the anode resistances to about 1,000 ohms to ensure a good frequency characteristic, hence the voltage amplification will fall from 15 to about 3 per stage and the receiver will be insensitive or uneconomical. Even with the use of valves of still steeper slope the receiver will remain most uneconomical while, as a rule, higher anode currents are required which may, of course, have to be increased to an impossible value before satisfactory values of gain are theoretically obtainable.

Another method which, however, is very useful is the employment of ordinary triodes with low internal impedance for the intermediate-frequency amplifier, the stages being coupled with

high-frequency iron-core transformers. With modern indirectly heated triodes and a small amount of staggering of the transformers, one can obtain an amplification of 16 times per stage with a sufficiently good frequency characteristic for the old standard of definition (180 lines, 0·5 Mc.).

With the values given for the circuit of Fig. 70, the sensitivity is sufficient, with a suitably arranged ultra-short wave aerial which is correctly matched with the appropriate feeder, to provide sufficient output voltage at distances of 12 to 18 miles from the transmitting station. At great distances from the transmitter, or where the aerial conditions are bad, only a small high-frequency voltage will appear at the grid of the first stage, so that it becomes necessary to operate the receiver at maximum sensitivity. In this case interference is easily produced in the picture. This interference becomes visible especially when the picture is viewed from a short distance. The interference arises from the shot noise of the receiver, and its presence is therefore a proof that the receiver is operating at the limit of useful gain and that any further increase of amplification will not provide better results. The shot effect shows up in the picture in the form of spots, particularly in the black portions and in the half-tones. In this connection it must be remembered that with very sensitive radio apparatus, in particular with frame receivers, the shot effect appears as a rustling noise. If the input potential is sufficiently high, the shot noise will disappear by correct adjustment of the picture brilliancy control. Only a small residual noise remains, which comes from the equivalent disturbance of the amplifier at the transmitter.

In the same way the sound amplifier is correctly adjusted for sensitivity if, by tuning the input circuit to the received frequency or by nearly correct tuning, the output stage is not overloaded. Overloading the output stage of the picture receiver results in streakiness of the picture, which is noticeable, in particular, in the transmission of film titles. Sensitivity is controlled by variation of the volume control resistance R10, in Fig. 70, which alters the slope of the variable mu valve V2. The two ultra-short wave coils for the input and oscillator circuits have $3\frac{1}{2}$ turns each, of a diameter of 30 mm. The coils have a length of 15 mm., and are self-supporting. In order to obtain good resonance, the input grid is connected to the centre of the coil and

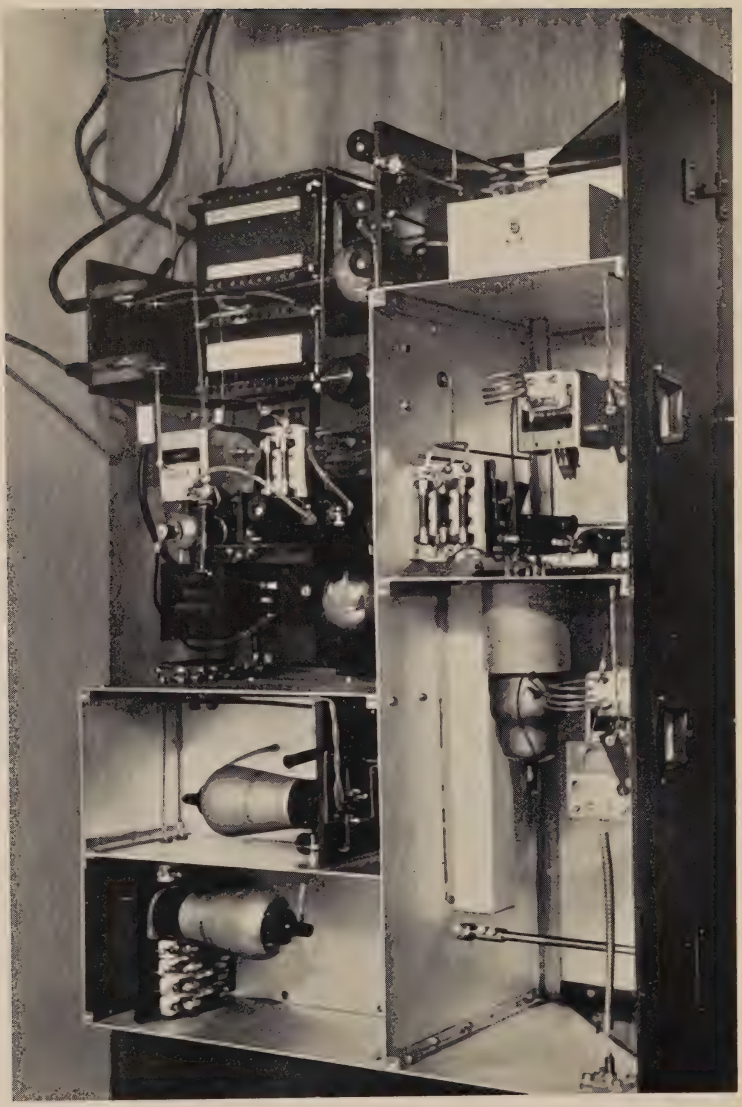

FIG. 71.—Inside view of the superheterodyne picture receiver.

[*To face p.* 99.

the coupling condenser C1 is made very small for the same reason. The intermediate-frequency circuit shown has proved satisfactory. The layout described below is such that no noticeable distortion is introduced into other television apparatus only a few metres away by radiation from the oscillator, since the latter is kept very low. Likewise, at distances of about 6 miles from the transmitter, with medium values of field strength, the oscillator radiation is still sufficiently low to enable adjacent receivers to operate without mutual interference.

The use of intermediate-frequency circuits which are reasonably free from radiation will prove necessary with increasing numbers of receivers in use, particularly when these receivers are located in areas of low field strength.

The method of operation of the mixing circuit need not be further described here, since this is already understood in connection with short wave reception, and, moreover, by using the stated values of resistance, in conjunction with the mains unit already described, an automatic adjustment of the working point and of the oscillator amplitude is guaranteed. The resulting intermediate frequency will then necessarily be of the correct amplitude in the aperiodic amplifier.

The final stage of the circuit of Fig. 70 is capable of providing a large output so that a substantial reserve of light control voltage is available, and suffices to provide extremely contrasty pictures in conjunction with the cathode ray tubes described herein.

B. Construction of a Superheterodyne Picture Receiver

The complete intermediate-frequency portion shown in Fig. 70 provides a voltage amplification of some 10^5 times. With such high amplification extremely small stray capacities and leakages between the output and input of the amplifier are sufficient to cause oscillation. Since the output of the circuit is, as a rule, connected with other parts of the apparatus by means of fairly long leads, the first stage of the intermediate-frequency amplifier must be well screened. By paying attention to the circuit layout and to the values given in Fig. 70, the back-coupling will be so far reduced that the amplifier will remain stable in spite of the

high gain. The actual construction of a receiver made to the circuit of Fig. 70 is shown in the photograph, Fig. 71.

A characteristic of this receiver is that the mains rectifier unit and the output stage, *i.e.*, those parts in which freedom from stray capacity is not necessary, are conveniently arranged, while the amplifier proper and the oscillator and mixer are given plenty of space and are well screened.

The photograph, Fig. 72, shows a rear view of the same apparatus. The other photograph, Fig. 73, gives a side view of the apparatus with the portions in the background covered with their metal screens. The photographs show all details, so that further description of the constructional arrangement of the parts is unnecessary. Only one further point, to which it is imperative that due attention be paid, will be discussed here.

In order to reduce oscillator radiation from the aerial, it is necessary to ensure that the oscillator circuit shall be decoupled from that of the aerial as far as is possible, *i.e.*, so far as the internal construction of the valve V1 will permit. The aerial feeder, coupling condensers, input circuit and leads to the first grid of the valve V1 are in a separate compartment. The oscillator coils and the various decoupling resistances, chokes and condensers are placed together in another small compartment.

The four amplifying stages, V2 to V5, are separately screened, and are arranged above and below one another.

The anode and grid leads are as short and as free from stray capacity as it is possible to make them. To this end the valves in the amplifier stages are so arranged that the sockets are at opposite ends of the compartments, and the photograph, Fig. 74, shows the arrangement of these stages, while Fig. 75 shows a later and even better arrangement. One can see from the photo the shortness of those leads in which freedom from stray capacity is of importance, and that the lead to the anode in each compartment is only a few centimetres long.

The use of screened leads for these few centimetres does not result in any noticeable increase in the anode-grid capacity. The unusually large band width of the intermediate-frequency amplifier is only obtained by reducing stray capacity to the utmost and by avoiding any appreciable additional capacity between the anode and grid leads of each stage.

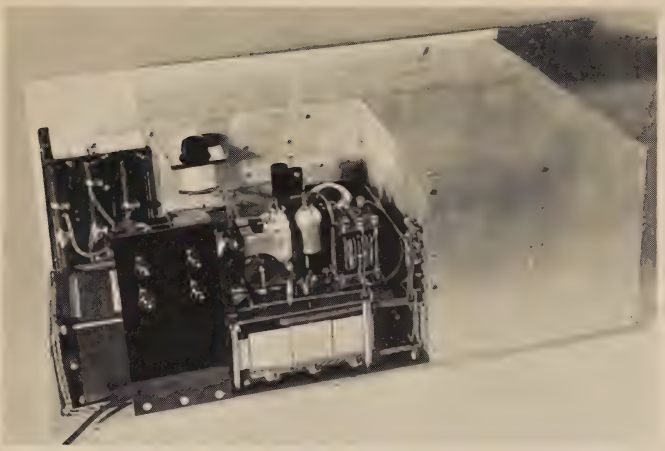

FIG. 72.—Rear view of the picture receiver.

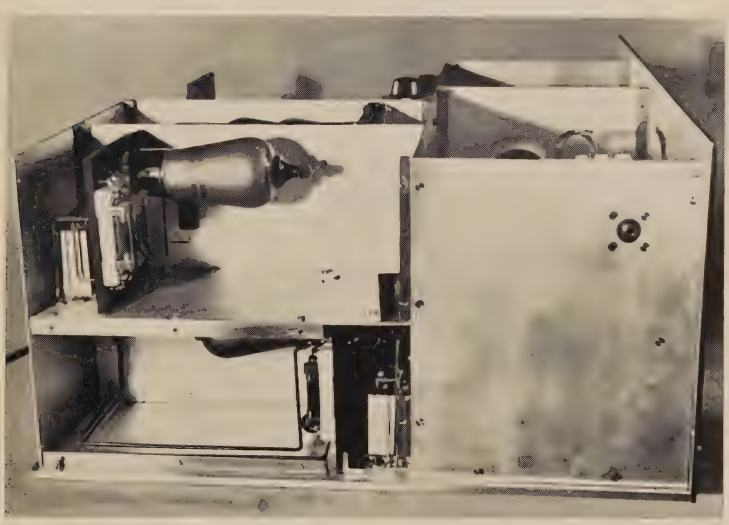

FIG. 73.—Side view of the receiver with part of the screening removed.

[*To face p.* 100.

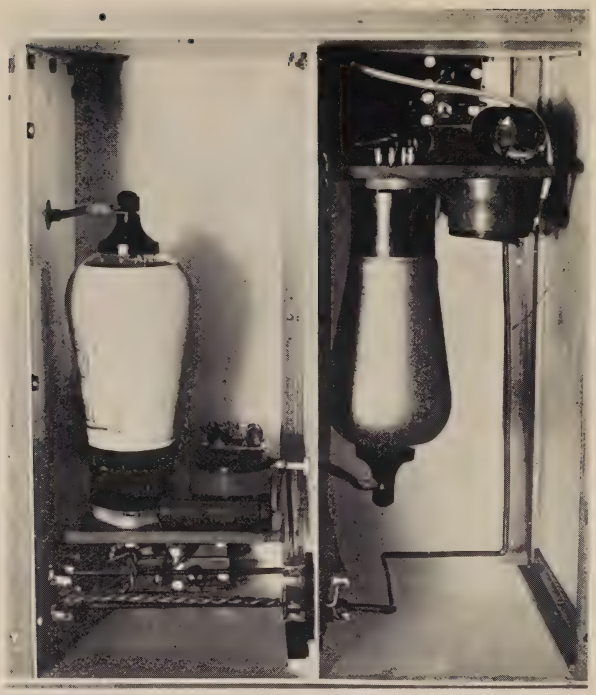

FIG. 74.—The arrangement of the intermediate-frequency portion of the receiver. (Note the short anode leads used to reduce the stray capacity.)

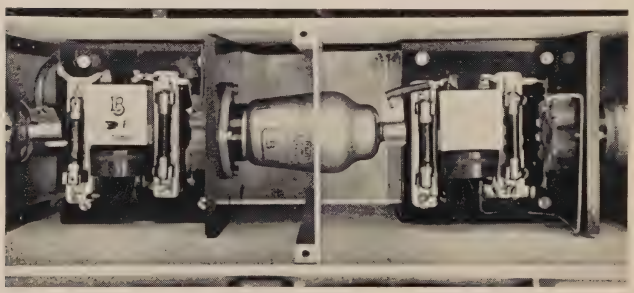

FIG. 75.—An improved construction of intermediate-frequency amplifier enabling the anode capacity to be still further reduced.

[*To face p.* 101.

Good screening of all the earlier stages, in particular of the input stage, and the careful decoupling of the heating and anode circuits result in good stability of the receiver in spite of the high gain and wide frequency range of the intermediate-frequency amplifier.

In order to avoid interference which might be detrimental to the synchronisation and definition, the screening of the input is so arranged that no coupling can take place between the aerial and any sensitive part of the intermediate-frequency amplifier. The aerial lead to the differential volume control condenser is screened, and so is the condenser itself.

Fig. 76 is a photograph of a fluorescent screen showing the effect of interference, due to sparking, on the appearance of a television picture. One observes that synchronisation remains satisfactory in spite of the strong interference.

Any tendency to oscillation in the mixing stage is the result of too little damping of the input circuit, and produces an obvious lack of sharpness in the picture. With small damping of the input circuit one can always see a noticeable effect of the input tuning on the character of the picture. It is recommended that, when tuning the receiver, the oscillator be first adjusted and that the input circuit be then adjusted again.

The output of the rectifier provides about 15 to 20 volts of picture signal, and the values for this portion of the receiver are designed to give an ample reserve. Various smoothing condensers may be omitted, or substantially smaller values may be used. The actual construction of this circuit is not very compact, indeed it is built on generous lines so as to leave space for future changes.

C. The Installation of the Receiver

It is advisable to make tests with headphones when putting the receiver into operation. The 'phones should be connected in place of the resistance R33, in Fig. 71. The correct tuning of the input circuit to the transmitter wavelength, balancing the aerial lead, adjusting the aerial coupling and oscillator condensers, testing the gain of the individual stages of the intermediate-frequency amplifier, testing the sensitivity control and the operation of the rectifier can all be carried out with headphones. If the superhet gives clear television signals without evidence of

oscillation, it is recommended that further adjustment be carried out while observing a picture.

The position of the receiver in the circuit of a television equipment is shown in the block schematic, Fig. 77. The drawing also shows the connections of the various parts of the apparatus.

The installation and lining-up of the television tube, mains unit and time base have already been described.

Before switching on the superheterodyne receiver one should

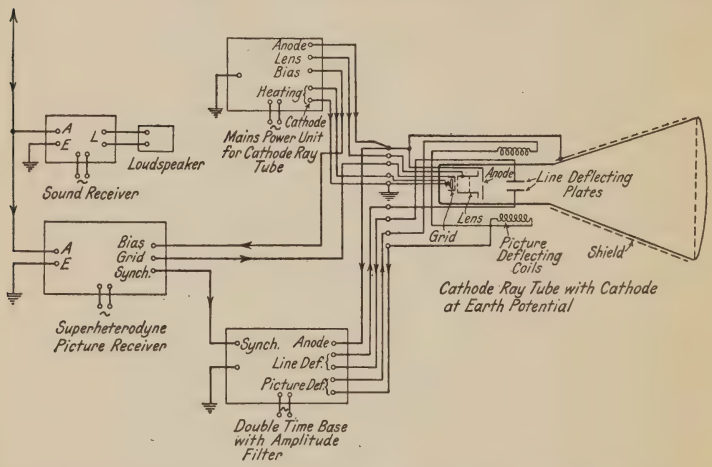

FIG. 77.—Block schematic diagram of the complete television receiving equipment.

obtain a raster of the approximate size required and of the correct format.

It is recommended that the width of the raster be made about 10 per cent. longer than is wanted in practice, since the synchronising signal causes the time base amplitude to be reduced by about this amount. The reduction of the amplitude in each direction forms a convenient indication of the adjustment of the synchronising impulse, which is controlled by the potentiometer in the grid circuit of the appropriate thyratron.

After adjusting the picture and line frequencies to approximately the correct values, and before switching on the radio receiver, it is necessary to adjust the negative bias on the grid of the cathode ray tube until the raster is just completely dark.

PLATE XXX

FIG. 76.—Typical distortion of the received image as a result of interference due to sparking, *e.g.*, from a tram trolley-wire.

[*To face p.* 102.

PLATE XXXI

FIG. 78.—Appearance of the picture with an incorrectly adjusted oscillator frequency. (Too low intermediate frequency.)

FIG. 79.—Plastic distortion due to exaggeration of the higher frequencies.

[*To face p.* 103.

After switching on the receiver, provided the picture carrier wave is being received, there appears, across the resistance R33, a D.C. potential which makes the bias point of the cathode ray tube go positive (*vide* Fig. 67), so that the raster again becomes visible.

After tuning the input circuit to the carrier wave, the oscillator must be adjusted. If it is desired to use only one side band, the oscillator must be tuned so that the operating point on the frequency curve of the receiver lies where the gain, towards the higher frequencies, is reduced to about a half. The simplest way to obtain good adjustment of the oscillator frequency is by comparison of the picture quality. With correct adjustment of the oscillator the intermediate-frequency carrier oscillations will just remain visible in the raster.

Correct adjustment of the oscillator frequency is essential for good picture quality. If the oscillator frequency is too close to the transmitter frequency the intermediate frequency becomes too low and the spots which then appear spoil the definition of the picture. Fig. 78 shows the effect of an intermediate frequency which is too low. If the frequency difference be made too great the intermediate-frequency carrier will be displaced outside the frequency range in which high amplification is obtained. The resulting greatly reduced sensitivity of the receiver provides very dark pictures, even with excessively high field strengths. Moreover, with this oscillator frequency setting the picture has a characteristic distortion, viz., that only the high-frequency overtones remain and, at the boundaries where a change of tone should exist, there is left only a whiter and a darker edge. This distortion is known as plastic. Fig. 79 gives an impression of this form of distortion in which the picture, which is shown correctly in Fig. 14, has the lower frequencies attenuated and the higher frequencies exaggerated. Correct adjustment of the oscillator is obtained when the plastic just disappears from the picture. One must arrange, by operation of the volume control and the cathode ray tube bias control, that the raster is barely visible in the absence of a transmission. The adjustment of the condenser C32, which controls the amplitude of the intermediate-frequency voltage on the grid of the amplitude filter, is best carried out during a picture pause. This condenser is so adjusted that, with the receiver already tuned, the maximum current flows in the

anode circuit of the amplitude filter. It is advisable to adjust the static working point of the filter characteristic before carrying out this test. The condenser C32, which must have a very low minimum capacity, is then correctly adjusted when, during the picture pause, a small reduction of capacity reduces the filter anode current.

Correct adjustment of the static working point of the filter and of the condenser C32 are essential for stable synchronisation of the picture. With high intermediate-frequency amplitude and low grid capacity to earth in the filter circuit, too much potential may appear on the grid. In this case it is recommended that a condenser of about 50 to 100 mmf. be connected between the synchronising terminal and earth, in Fig. 70. This condenser must not be greater than is absolutely necessary, since the load on the output stage must remain as small as possible in order to obtain large signal voltages. Finally, it must be mentioned that, as in long wave reception, accurate tuning of the input circuit to the carrier wave does not always give the best results. It is often better to tune the receiver a little towards the shorter waves.

If too small an input potential to the receiver is obtained, or if there is insufficient amplification, the filter may not provide sufficient amplitude of synchronising signal. At the same time, of course, the brilliancy control potential will also be too small and the total result will be bad synchronisation and lack of contrast in the pictures. A typical picture obtained with too small a signal amplitude is shown in Fig. 80. If the trouble is due to insufficient input and output potentials, it is recommended that the aerial arrangement be improved as described in the following chapter.

Fig. 81 shows a view of the collection of units which go to make up a television research receiving equipment. On the extreme left is the radio receiver, then follow the mains unit, television tube with loudspeaker, double time base and sound receiver.

With an arrangement in which the apparatus is required for research purposes, and where future circuit variations must be allowed for, it is advisable to arrange the complete equipment in separate units which are controlled independently. The chief difference between research and industrial apparatus lies in the

PLATE XXXII

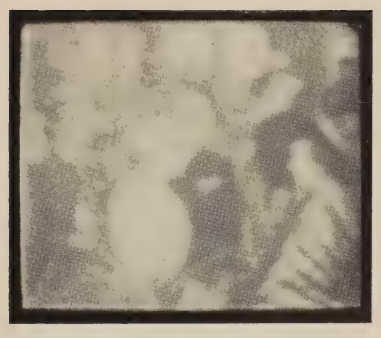

FIG. 80.—Lack of contrast due to insufficient intermediate-frequency amplitude or too much bias on the grid of the cathode ray tube.

[*To face p.* 104.

PLATE XXXIII

FIG. 81.—Units forming a television receiver for research purposes.

[*To face p.* 104.

PLATE XXXIV

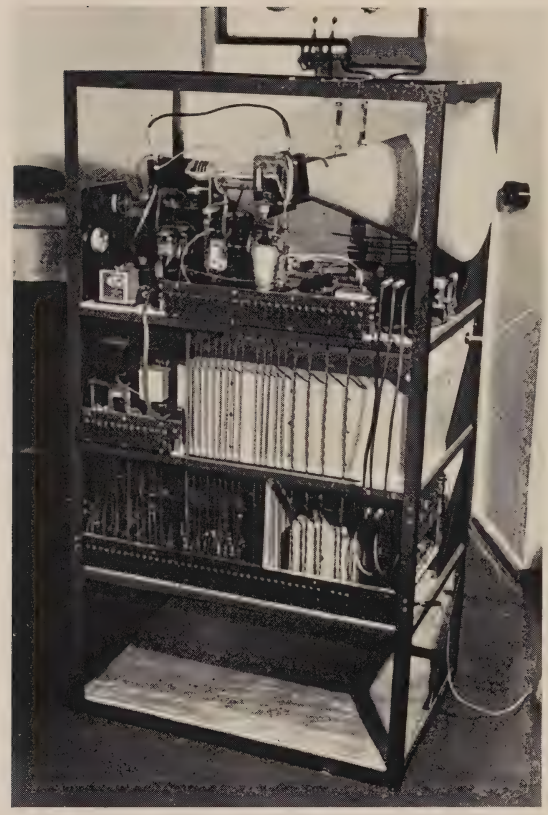

FIG. 82.—View of the inside of a television receiving equipment (frame construction).

[*To face p.* 105.

form of construction, the latter always being built as a single instrument. Furthermore, the apparatus described can be built into a compact unit with few alterations. Fig. 82 shows an example of such a receiver in which all the component parts are built into one frame. The cathode ray tube is shown on the upper deck, together with the two time bases. On the centre deck lies the picture receiver and, underneath, the various mains units for the tube, time base and receiver. The raster is completely free from magnetic interference due to the large distance between the cathode ray tube and the mains transformers.

D. The Aerial

A good receiving aerial is necessary at the receiving station if good picture reproduction is to be obtained with small field strengths. With a suitable arrangement of the aerial, it is not only possible to reduce the number of stages in the picture and sound receivers, but to increase the signal to noise ratio.

Normal broadcasting aerials can be used at small distances from the transmitter, particularly when the aerials are fairly high. They cannot be recommended, however, because the absence of aerial tuning results in an unnecessarily high noise level and, furthermore, there is danger of broadcast transmitter interference in the intermediate-frequency amplifier. In this respect, much better results are obtained with a short wire, if possible, arranged vertically in the room. The aerial should have a length of about $\lambda/2$ from the aerial terminal of the receiver to its far end. This arrangement has, however, the disadvantage that, with every movement of persons in the room, variations of the input voltage are produced which can only be overcome by automatic volume control or by frequent readjustment. Also, inside aerials, particularly on the lower floors of buildings and at great distances from the transmitter, often provide too small an input voltage. In this connection it may be mentioned that small changes of position of the aerial effect very considerable variations of input voltage. Changes of input voltage in a ratio of 1 to 10 are absolutely possible. In order to obtain the highest possible input voltage, in spite of distortion of the field due to interference from reflected waves and absorption inside buildings, the best position in the room for the aerial must be ascertained by experiment.

An aerial which is considerably better than an inside one is shown in Fig. 83. The aerial is a high vertical wire of a length of $\lambda/2$ metres which, for the present Berlin wavelength, is about 3·3 metres long. The aerial is erected as high as possible and, if local conditions permit, it is arranged within optical sight of the transmitting aerial.

FIG. 83.—Receiving aerial with tuned feeder.

To the lower end of the aerial a two-wire feeder is connected which leads to the input terminals of the receiver. Only one wire of this line must be connected with the aerial, while the second one is free. The distance between the wires must be very small compared with the wavelength, for example, 30 to 50 mm. One must take care that the distances remain equal for the whole length of the feeder, by inserting distance pieces of a material which is a good insulator at these frequencies; for example, Kalit might be used. One must avoid bringing the feeder near buildings. The feeder must be tuned, this being carried out by shortening or lengthening the receiver end of the feeder until standing waves appear on the aerial and feeder. As the coupling conditions to the receiver depend upon the afore-mentioned adjustment, it is recommended that the optimum length be obtained by experiment. The mechanical construction of ultra-short wave aerials is shown in Fig. 84.

Fig. 85 shows another form of ultra-short wave aerial. With this arrangement the feeder impedance is matched to that of the input circuit of the receiver at one end and to the impedance of the receiving dipole at the other. The feeder is brought away at right angles from the centre of the aerial. The maximum transmission efficiency is obtained when the feeder faces its own

PLATE XXXV

FIG. 84.—The construction of an ultra-short wave aerial.

[*To face p.* 106.

impedance at each end. The length of the feeder, which is arranged as shown in Fig. 85, need not, in this case, be adjusted to any special value. The latter method of construction is especially recommended when both the picture and sound programmes are to be received on the same aerial. The receiving dipole must be adjusted as though only the picture is to be received.

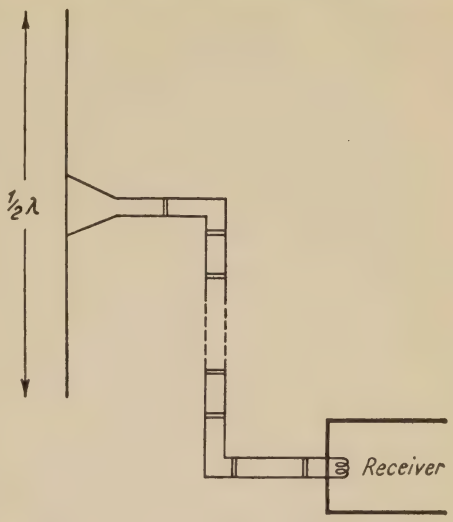

FIG. 85.—Receiving dipole with matched feeder.

If, with very bad receiving conditions, the input voltage is still insufficient to modulate fully the cathode ray tube, the use of more or less directional reception is recommended. In particularly bad cases the insertion of a high-frequency stage in front of the receiver described in this chapter will be necessary. A further loose-coupled oscillatory circuit, together with an extra valve, must be added to the circuit in front of the mixer valve.

CHAPTER VIII

THE SOUND RECEIVER

In order to receive the sound which accompanies the television picture a receiver is necessary, and it must possess approximately the same sensitivity as that of the picture receiver. Since, however, only a narrow frequency band of about 10,000 cycles is transmitted for the sound, it is, in principle, sufficient to use a normal receiver

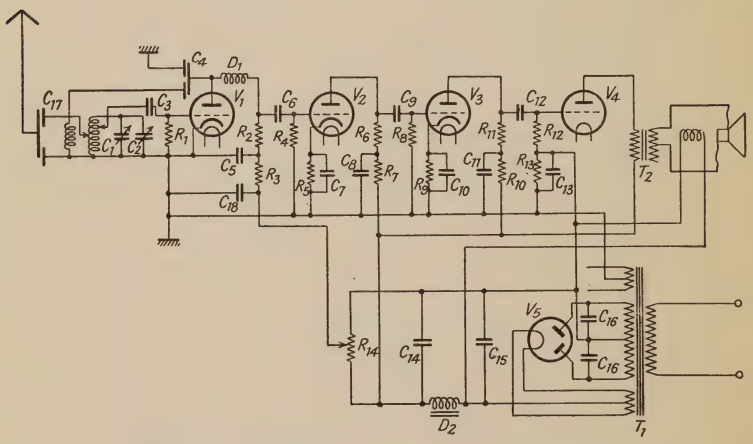

Fig. 86.—An ultra-short wave sound receiver.

with reaction and with a larger amount of low-frequency amplification. Since such circuits and their operation are already generally understood, due to their use in the construction of broadcast apparatus, the author will treat the subject in a non-detailed manner. The circuit used is shown in Fig. 86.[1] An ordinary reactive detector arranged for ultra-short waves is followed by three resistance-capacity coupled stages. The arrangement of the ultra-short wave and volume-control circuits is exactly similar to that already described for the picture receiver.

[1] Another circuit which may be recommended for a 5 metre sound receiver will be found in *The Wireless World*, October 11th, 1935.

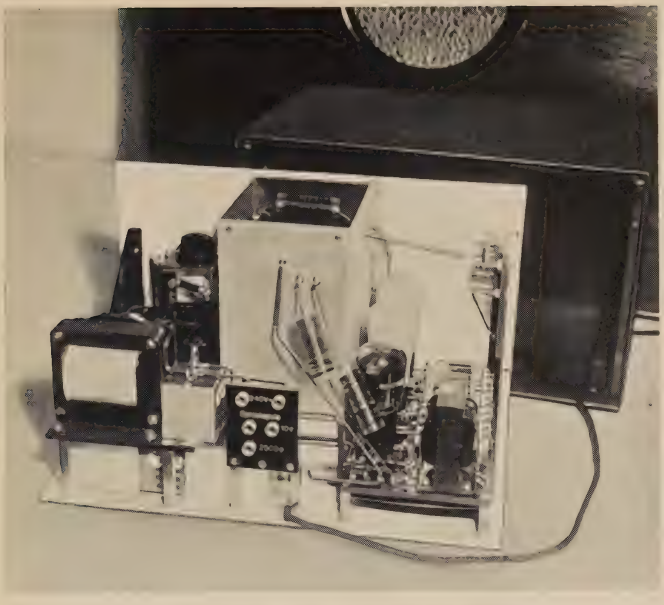

FIG. 87.—Rear view of the sound receiver.

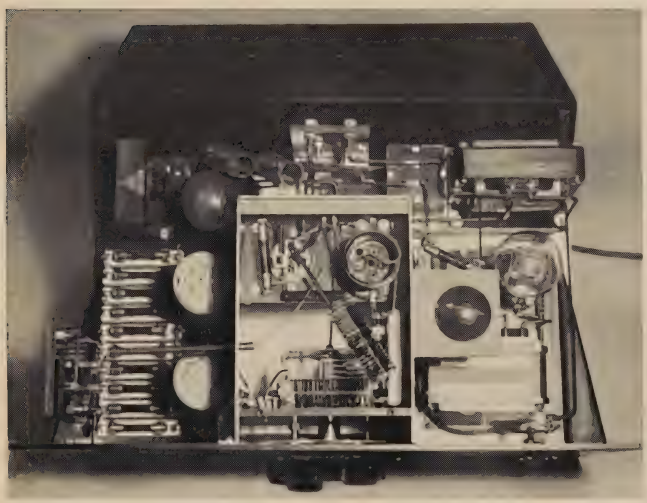

FIG. 88.—View of the sound receiver from above.

[*To face p.* 108.

PLATE XXXVII

FIG. 89.—The sound receiver.

[*To face p.* 109.

Reaction is controlled by means of a small differential condenser. The inductance of the ultra-short wave circuit is again in the form of a self-supporting coil of three turns, with a winding diameter of 3·3 cm. and a length of 0·8 cm. Also, in this case, the grid of the input valve is connected across only a part of the coil in order not to damp the input circuit to too great an extent. Low input damping is necessary so that, even at small distances, a sound transmitter can be separated from a picture transmitter having an extended frequency band, without the use of reaction. The ultra-short wave stage must be constructed with the shortest possible leads.

In general the same aerial may be used for both radio receivers. The reduction of input voltage to the picture receiver when tuning in the sound receiver is generally too small to be taken into account. In cases where this is not so a short separate wire may be used as an aerial for the sound receiver.

It will be necessary to use reaction to increase the sensitivity, even at distances of 5 to 6 miles from the transmitter. The reaction coil consists of two turns of 3·8 cm. diameter and, in the receiver described herein, they are arranged with a fixed coupling to the grid circuit coil. For fine tuning a vernier condenser of about 5 mmf. is connected in parallel with the main tuning condenser. In setting up the apparatus, one must take care that the ultra-short wave circuit is undamped. Other details are given in the circuit, and the necessary values are shown on page 110. A practical form of the circuit of Fig. 86, in which the ultra-short wave part of the circuit is housed in a separate screened box, is shown in the photograph, Fig. 87. On the left is the mains rectifying unit, while the low-frequency amplifier is seen on the right. A view of the same apparatus from above is shown in Fig. 88, while Fig. 89 shows an external front view of this relatively simple receiver.

The possibility of combining the two receivers was discussed in the first chapter. Even in the sound part, it is recommended that intermediate-frequency amplifiers with a narrow pass band be used where a high grade of performance is required or where the apparatus will be used by laymen. Such receivers have an advantage over reaction receivers in that their operation is easier and their sensitivity higher. Whether a common oscillator and mixer be used, or otherwise, depends upon the existing conditions,

and, in particular, upon the frequency separation of the picture and sound-carrier waves.

Parts List for the Circuit of Fig. 86.

R1	1	megohm	
R2	7,000	ohms	
R3	5,000	,,	
R4	1	megohm	
R5	3,000	ohms	
R6	0·4	megohm	
R7	0·05	,,	
R8	1	,,	
R9	10,000	ohms	
R10	0·02	megohm	
R11	0·1	,,	
R12	1	,,	
R13	800	ohms	
R14	50,000	,,	
C1	50	mmF.	
C2	5	,,	
C3	150	,,	
C4	2 × 100	,,	
C5	4	MF.	1,500 volts
C6	5,000	mmF.	1,500 ,,
C7	20	MF.	10 ,,
C8	1	MF.	1,500 ,,
C9	5,000	mmF.	
C10	20	MF.	10 ,,
C11	1	MF.	1,500 ,,
C12	5,000	mmF.	1,500 ,,
C13	20	MF.	50 ,,
C14	8	MF.	1,500 ,,
C15	6	MF.	1,500 ,,
C16	2 × 0·1	MF.	3,000 ,,
C17	2 × 10	mmF.	
C18	6	mmF.	500 ,,
V1		MFH (Cossor)	
V2		MH ,,	or 994V (Mullard)
V3		MFH ,,	
V4		4XP ,,	
V5		442BU ,,	
D1	Ultra-short wave choke.		
D2	Smoothing choke. 50 H. 50 ma.		
T1	Secondary 2 × 350 volts 50 ma. Heaters 4 volts, 5A. centre tapped. Rectifier 4 volts, 2A. centre tapped.		
T2	To suit loud speaker employed.		

PLATE XXXVIII

FIG. 90.—Unretouched photograph of a visual image from the Berlin (Witzleben) station. (Received at Lichterfelde with the apparatus described herein.)

[*To face p.* 110.

PLATE XXXIX

FIG. 91.—Photos taken during the transmission of the film "Victor and Victoria."

PLATE XL

FIG. 92.—Enlargement of a portion of a picture (Fig. 91) for examination of the raster and overall definition.

[*To face p.* 110.

FIG. 93.—Further characteristic photographs from the Berlin (Witzleben) transmissions.

FIG. 94.—Pictures received on a single side band superheterodyne receiver.

[*To face p.* 111.

CHAPTER IX

RESULTS OBTAINED

A TELEVISION programme can be regularly received for long periods of time, with the equipment described, at places where the field strength is reasonable, and pictures which are very free from trouble will be obtained.[1] The high-vacuum cathode ray tube, as well as the picture receiver and rectifier described herein, will ensure good picture definition.

The picture brilliancy may be so high, even, with a large format (18 × 22 cm.), that the limiting value of raster brilliancy, due to the commencement of 25-cycle flicker, may be far exceeded. This will not occur with the interlaced scanning method of transmission as used by the Marconi E.M.I. Company. Contrasty and undistorted pictures will be obtained, since neither the line nor the picture fly-backs are visible.

Synchronisation will remain stable in both directions so that the picture remains steady, even over long periods of time. The synchronising signal can be so adjusted in both directions that no noticeable line or picture displacement will occur during a transmission. The accompanying sound is also satisfactory.

Unretouched photographs, taken directly off the screen of the cathode ray tube, are shown in Figs. 90 to 96. Fig. 90 shows a visual announcement from the Berlin transmitter, while the following pictures, Figs. 91 to 94, show scenes and titles from sound films. Since the pictures are so bright, photographs may be taken with exposures of a fraction of a second, so that sharp reproduction is possible in spite of movement in the film picture. Some of the above-mentioned pictures were obtained with double side band reception ; with single side band working noticeably sharper definition is obtained. Figs. 90, 94, 95 and 96 were obtained with the single side band arrangement. The impression

[1] Messrs. A. G. Lorentz, of Berlin-Tempelhof, own a number of patents in connection with the use for television of some of the circuits and apparatus described in the preceding chapters.

obtained directly from the television receiver is still more favourable since, on account of the movement and of the change to new raster elements, sharper definition is obtained. Furthermore, the accompanying sound brings increased interest in the performance.

In commenting upon the pictures, the reader must note that most of them were taken in the autumn of 1934, and that before the end of the following January improvements were made to the frequency characteristic of the Berlin transmitter which brought about a substantial improvement in the definition. Further, the sharpness of the spot, in the direction at right angles to the lines, is less in the fluorescent screen photographs than is actually the case. The effect of this was that, at any rate during autumn of last year (1934), successive pictures were not quite of optimum quality due to defects in the transmitter scanning. In places one can observe a change of picture position of two or three line widths.

Two pictures, which were taken later than the others, are shown in Figs. 95 and 96. Since black lines, which are of equal blackness in the various directions, appear in Fig. 95, this picture is a good one from which to judge the sharpness of the spot at right angles to, and along, the lines. In judging these photographs of television images one must remember that the quality of the picture is obviously limited by the present standard of definition (180 lines) of the Berlin transmitter.

Since television receivers are not at the present time on the market, and since circuits have not been published until now, the author unfortunately has to limit himself to the results of the experiments and technical work which he has carried out during the last few years.

The final results have proved to the author that the methods used were correct; whether they are the simplest methods will be discovered when other laboratories, working on the development of television, publish some of their results and methods.

One of the chief problems in connection with the future development of television is, as mentioned before, the reduction of the price of apparatus. A television receiver requires many amplifying and rectifying valves besides the cathode ray tube, and there are also a large number of cheap resistances and condensers and a few short wave circuits which must be capable of

PLATE XLII

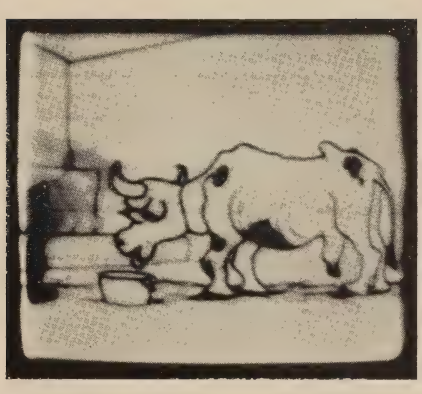

FIG. 95.—Photograph from a cartoon from which one may judge the quality of the definition either across or along the lines.

[*To face p.* 112.

FIG. 96.—View of the receiver in operation during the reception of an announcement from the Berlin (Witzleben) station. The picture shows the announcer in a light-beam transmitting booth.

[*To face p.* 113.

cheap production. It is important that valve manufacturers should settle the question of price at an early date, as the development of television is certainly very much dependent upon it. Only when it is possible to obtain the valves necessary for television apparatus at prices which are considerably lower than those which now apply, will the production of such television apparatus be possible at prices which are within the reach of the public at large.

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INDEX

ABSORPTION of ultra-short waves, 12
A.C. heating, 44, 47
Accelerating lenses, 30
Aerials, 12, 105
  directional, 13
Alexandra Palace, 5, 12
Alignment of electrodes, 44
Amplification,
  aperiodic, 15
  high-frequency, 13
  intermediate frequency, 79
  paraphase, 62, 70
  stage, 93
  time base, 55, 63
Amplitude,
  filter, 17, 62, 67, 76, 80
  filter adjustment, 104
  of synchronising impulse, 68, 80
Anode current characteristic of cathode ray tube, 32
  volts characteristic of cathode ray tube, 33
  volts for cathode ray tubes, 41, 43
Aperiodic amplifier, 15
Ardenne, M. von, 4, 21, 36, 57, 60, 64
Asymmetric deflection, 28, 44
Astigmatism, 44
Author's cathode ray tube, 32

BAIRD Company, 5, 10, 13
Balanced deflection, 28, 62, 69
Band of frequencies, 76
Band-width, 13
Baneitz, F., 4
Bas-relief distortion, 69
Beam,
  convergence angle, 25
  current, 32, 37
  diffusion, 25
  divergence angle, 24
  modulating potential, 41, 43
Bedford, L. H., 4, 29, 60
Berlin,
  transmitter, 3
  wave-form, 15
Bias potential, 41, 43, 47
Brilliancy
  characteristic, 32, 45
  control, 32
  of picture, 111
  of raster, 34
Broadcast sound reception, 2, 14
Brücke, E., 29
Burning of screen, avoidance of, 45, 58

CANDLES, Hefner, 34
Candle power, 34
Capacity,
  stray, 62, 73, 90, 93, 99
  unbalance in transformers, 90
Carrier
  frequency, 49
  peak, 8
Cathode ray tube,
    advantages for television, 23
    anode current characteristic, 32
      earthing of, 45
      potential for, 41, 43
      volts characteristic, 33
    Author's, 32
    beam concentration, 24
      generation, 30
    brilliancy characteristic, 32, 45
    cathode earthing of, 45
    Cossor, 43
    deflectional sensitivity of, 41, 43
    double modulation in Cossor, 43
    electrode alignment in, 44
    equipotential surface of, 44
    gas-focussed, 23
    heating current for, 47
    high vacuum, 23
    modulating potential for, 41, 43
    rectification in, 86
    sizes, 41, 43
    socket, 42, 44
    temperature inertia of, 45
Characteristic, frequency-amplitude, 90, 97
Charging valves, 55, 60
Coils, ultra-short wave, 98, 109
Colour
  of screen illumination, 35
  television, 77
Combined receivers, 109
Commission on Illumination, International, 39
Compensating circuits, 62
Convergence angle, 25, 27

Cossor, A. C., and Company, Ltd., 43, 44, 46, 49, 52, 60, 110
Critical enlargement of spot, 27
Current, time base, 20
Cycle diagrams of time base, 63
Cylindrical lens, 28, 44

DAMPING, 66, 90
Decoupling of receiver, 100
Definition
in line direction, 76
in picture direction, 76
or sharpness, 22, 56, 69
standards of, 2
Deflecting coils, 29, 75
Deflection,
asymmetric, 28, 44
electrostatic, 27, 41, 43, 70
magnetic, 20, 27, 69
symmetrical, 28, 62
Deflectional sensitivity, 41, 43
Deflector
plates, 28, 43, 70
plate leakage paths, 67
Demodulation of low frequencies, 92
Diameter
of lens, 26
of spot, 18, 32
Diaphragms in lenses, 32
Diffusion of the beam, 25
Dipole, 106
Directional aerials, 13
Discharge time of time bases, 55, 66, 69, 70
Discharge valves, 56, 59, 61, 70
Displacement of lines, 69, 80
Distortion,
magnetic, 51, 78
of field, 105
origin, 24
plastic, 69, 103
raster frequency, 76
Divergence angle, 24
Double modulation in Cossor tube, 43

EARTHING, 45, 50
Electrode alignment, 44
Electron lens, 24, 30
Electron-optics, 17, 44
Electrostatic
deflection, 27, 41, 43, 70
screen, 75
Element of picture, 32
Emission, secondary, 42
Equipotential surface, 44
Extinction potential, 54

FACTORS
of illumination, 35
of visibility, 39
Feeders, 12, 106
Field distortion, 105
Field-strength magnitude, 12, 58
Filter, 84
amplitude, 17, 67, 76, 80
adjustment, 104
Firing potential, 54, 61, 69
Flicker, 18, 21, 34, 111
Fluorescence, 38
Fluorescent screen materials, 36
Flyback
lines, 20, 68
time, 20, 29, 56, 57, 66, 69, 70, 73
Focus of lens, 31, 49
Format, picture, 4, 6, 11, 42, 58, 76
Frequency,
amplification at high-, 13
band, 76
characteristic, 90, 97
frame (Baird), 11
(Marconi-E.M.I.), 5
intermediate, 89, 91, 92
line (Baird), 11
(Marconi-EMI), 5
of carrier, 49
of picture change, 34
of radio transmitters (Berlin), 4
of radio transmitters (London), 4
of raster, distortion of, 76
of synchronising signals (Berlin), 15
of time base, 55, 56

GAS
discharge triodes, 59
ions, inertia of, 24
German Post Office, 12
Glaser, A., 59
Glass charges, 24
Grid current, 68
locking, 63

HALO distortion, 42, 43
Heater windings, 74
Heating, A.C., 44
Hefner candles, 34
High-frequency amplification, 13

ILLUMINATION,
factors, 35
International Commission on, 39
of screen, 34, 35
Imaged object, 30, 43

Inertia
for picture reception, permissible, 2
for sound reception, permissible, 2
of gas ions in cathode ray tubes, 24
temperature, 45
Interference, 51, 69, 73, 77, 98, 99, 101, 105
by radiation, 99
Interlacing, 8, 21, 111
Intermediate frequency, 89, 91, 92
amplifier, 79
smoothing, 88
transformers, 98
Iron core
deflecting coils, 29
transformers, 98

LAMPLIGHT spectra, 40
Leading-out wires, 42
Leakage paths for deflector plates, 67
Lens,
accelerating, 30, 44
astigmatism, 44
cylindrical, 28, 44
diameter, 26
diaphragms, 32
electron, 30, 44
focus, 31
magnetic, 30
potential, 41, 43, 47
prismatic, 44
Leybold und von Ardenne Oscillographen-Gesellschaft, 41, 49
Light wavelengths, 40
Limiting resistances, 50, 67
Line
amplitude, 77
definition, 76
displacement, 69, 80
frequency, 5, 11, 76
Linearity of time base, 55, 66
Lines,
flyback, 20
scanning, 20
slipping, 21
wandering, 21
Lorentz, C., Ltd., 3
Lux, 34

MAGNETIC
deflection, 20, 27, 69
distortion, 51, 78
screening, 51
Magnification of cathode ray tube spot, 27, 30
Mains units, 47
Marconi-E.M.I. Company, 5, 13, 21
"Stabilivolt" stabilisers, 55
Modulation
D.C., 7
potential, 41, 43
vision, 7
Mullard Radio Valve Company, 95, 110

NEON lamp
extinction, 54
firing potential, 54
striking potential, 54
time base, 54
stabilisers, 55
Noise
interference, 69, 98
level, 69, 105

OPTICS, electron, 17
Origin distortion, 24
Oscillator
adjustment, 97, 103
heterodyne, 97
radiation, 98
Oscillogram
of Berlin transmission, 15
of condenser discharge time, 56
of high vacuum time base, 63
of magnetic deflection current, 20
Osram Valve Company, 95
Output
stage of I.F. amplifier, 91
transformer, 90

PARAPHASE amplifier, 62, 70
Peak carrier, 7
Phase relations in time bases, 56, 68, 78
Phosphorescence, 38
Picture
amplitude, 76
brilliancy, 111
definition in direction of, 76
element, 32
format, 42, 58, 67
(Baird), 11
(Berlin), 4
(Marconi-E.M.I.), 6
frequency, 5, 11, 76
sharpness, 22, 27, 49, 56, 69, 88
Plastic distortion, 69, 103
Plates, deflecting, 28, 43, 70
Post Office, German State, 4
Potential,
extinction, 54
striking or firing, 54
time base, 54

Potentials for cathode ray tubes, 41, 43, 47
Power units, 47
  Author's, 48, 50
  Cossor, 48, 52
Prisms, 44

RADIATION, straight line, in ultra-short waves, 2
Raster, 20, 76
  adjustment, 102
  brilliancy, 34
  frequency distortion, 76
Ray
  convergence angle, 25
  current, 32, 37
  diffusion, 25
  divergence angle, 24
  modulating potential, 41, 43
Reaction, 109
Receiver
  decoupling, 100
  for picture and sound, 109
  picture superheterodyne, 92
    sensitivity, 98
Receivers,
  sensitivity of, 12
  type of, 12
Reception tests at Lichterfelde-Ost, 3
Rectification,
  full-wave, 88
  in the cathode ray tube, 86
Rectifying valves, 49
Reichspostzentralamt, 12
  experiments, 12
Ripple in time bases, 74

SAFETY resistances, 50, 67
Scanning
  frequency, 5, 11, 76
  lines, 20
Scherzer, O., 29
Scholz, W., 3
Schriever, O., 22
Screen
  burning, avoidance of, 45, 48
  colour, 35
  electrostatic, 75
  fluorescence, 38
  illumination factors, 35
    (wavelength), 35
  magnetic, 51
  materials, 35
  phosphorescence, 38
  saturation, 32, 38
  spectra, 40
Screening of receiver, 100
Secondary emission, 42
Sensitivity
  of picture receiver, 98
  of receivers, 12
  of sound receiver, 98
Sharpness of definition, 22, 27, 49, 56, 69
Shot noise, 98
Side
  band reception, single, 92, 111
  bands, 91, 92
Signal-
  noise level, 105
  waveform, 10, 11, 15, 58, 79
Slipping scanning lines, 21
Slope, valve, 93, 97
Smoothing, 49, 67, 69, 73, 88
Socket for cathode ray tube, 42, 44
Space charge, 24, 25
Specific loading of screen, 38
Spectra of screen materials, 40
Spectral intensity distribution, 36
Spectrum of lamplight, 40
Spot
  diameter, 18, 32
  magnification, 27, 30
  sharpness, 27, 30, 88
Stabilisers, neon, 55
Stage amplification, 93, 97
Stereoscopic television, 76
Stray capacity, 62, 73, 90, 93, 99
Striking potential, 54
Superheterodyne receiver, 92
Supplies for heaters, 74
Supply mains ripple, 49, 74
Symmetrical deflection, 28, 62, 69
Synchro isation, 22, 55, 57, 62, 68, 76, 80
Synchronising
  impulse, 4, 7, 11, 15, 22, 55, 57, 68, 74, 80
  signal amplitude, 68, 80
  signals (Baird), 11
    (Berlin transmitter), 4, 15
    (Marconi-E.M.I.), 7
  valve, 62

TELEFUNKEN Company, 3
Temperature inertia, 44
Thyratrons, 59
Time base
  adjustments, 76
  amplification, 55, 63
  charging valves, 55, 60
  compensating circuit, 62
  cycle diagrams, 63
  discharge time, 55, 57, 69, 70, 73
    valves, 56, 59, 61, 70
  distant operated, 57

Time base—*continued.*
extinction voltage, 54
firing voltage, 54, 61, 69
frequency, 55, 56
grid current locking of, 63
high vacuum valve, 55, 60
linearity, 55, 66
neon lamp, 54
phase relationships, 20, 56, 68, 78
ripple, 74
self-running, 57
synchronisation, 57
synchronising valve, 62
transformer, 66, 70
bases, 19
mutual interference in, 74, 77
constant, 62, 67, 70, 73, 90
Transformer,
output, 90
time base, 66, 70
Transformers,
iron core, 98
intermediate frequency, 98
Transmitted wave form
(Baird Company), 10
experimental (Baird Company), 11
(Marconi-E.M.I. Company), 5
Transmitter
field strength, 12
radio (Berlin), 3
Transmitters,
radio (London), 5
for television, 3

VALVE slope, 93, 97
Valves,
discharge, 56, 59, 61, 70
rectifying, 49
Visibility factors, 39
Voltage doubling, 49

WANDERING lines, 21
Wave absorption, 12
Waveform
of signal, 5, 8, 10, 11, 15, 79
of time base, 19
transmitted
(Baird), 10
(Berlin), 15
(Marconi-E.M.I.), 5
modified experimental form of, 11
variations in, 8
Wavelength of screen illumination, 35
Wavelengths of light, 40
Width of band, 13

ZWORYKIN, V. K., 29

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